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By Josiah Parsons Cooke, *Director*.

Presented May 11, 1881.

Introduction.

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Presented May 11, 1881.

INTRODUCTION.

IN a paper presented to the Academy, and published in its proceedings, Vol. XIII., page 1, we gave the results of our investigation of the haloid compounds of antimony up to that time, including a revision of the atomic weight of this element. We did not directly answer the criticism which this paper called forth, except so far as to present to the Academy, March 10, 1880, and to publish in these Proceedings, Vol. XV., page 251, a preliminary notice of experiments then in progress which furnished the best possible answer to the unfounded assumptions of the critic. We also gave brief notices of our work from time to time in the American Journal of Science. But now that the work is ended for the present (or at least must be suspended for a considerable period), we propose to bring the results together in the present paper.

I. THE OXIDATION OF HYDROCHLORIC ACID SOLUTIONS OF ANTIMONY IN THE ATMOSPHERE.

In our first paper (loc. cit., page 21) we made the following incidental observation, in explanation of certain precautions which we found to be necessary in order to secure the precipitation of pure antimonious sulphide: —

"The precautions here described may seem unnecessary to those who are not familiar with the fact that a solution of antimony in hydrochloric acid oxidizes with very great rapidity in the air, — fully as rapidly as the solution of a ferrous salt. A solution reduced as we have described, which has at first no action on the iodized starch paste, will strike the blue color after it has been exposed to the air for only a few minutes. This property of an acid solution of antimonious chloride is mentioned by Dexter, in the paper already referred to, but we were wholly surprised by the energy of the action. By means of it, antimony can be dissolved in hydrochloric acid without the aid of nitric acid, or of any other oxidizing agent save the air, if only a certain amount of antimonious chloride has once been formed. When, after exposure to the air, the solution is boiled over pulverized antimony, the solution is reduced, and a further portion of the metal enters into solution. After a second exposure, the same process can be repeated, and so on indefinitely. The process is very slow and tedious, but, in one experiment, we succeeded in bringing into solution in this way several grammes of antimony."

On the sole basis of this language we have been represented as asserting that such antimony solutions oxidize in the air as rapidly as a solution of *ferrous chloride*, and experiments on comparatively dilute solutions of antimonious oxide in hydrochloric acid have been adduced as proofs that our observation was incorrect.

As is evident from the context, the statement just quoted, although the result of a very extended experience, was not based on quantitative measurements. What we noticed was that the solutions *were very quickly acted on* by the oxygen of the atmosphere, and we freely admit that the expression here italicized is a more accurate description of our observation than the words originally used as quoted above. But our meaning was not left in doubt, for we expressly say, immediately after, that the process is very slow and tedious. In regard to the phenomenon in question, the effects are so obvious, when once attention is called to them, that it is entirely unnecessary to confirm our previous observations except so far as to add the following quantitative determinations, which will serve to give an accurate idea of the extent of the action under the only conditions we have investigated, or in regard to which we have written.

In order to determine the amount of oxidation caused by the action of the atmosphere on a solution of antimony in hydrochloric acid, we reduced the oxidized solution by boiling the liquid over antimony bullets, and determined the loss in their weight. This method is fully described in our original paper, and is based not only on the reducing power of the metal, but also on the fact repeatedly observed, that, after the reduction was complete, the smallest excess of the finely pulverized metal would not dissolve, even after prolonged boiling, and in the presence of a large excess of acid, if only the solution was protected from oxidation.

We began our experiments by dissolving 1.0036 grammes of pure antimony (a portion of the same used in our experiments on the synthesis of antimonious sulphide) in about 30 cubic centimetres of pure hydrochloric acid (sp. gr. = 1.175) adding 3 cubic centimetres of very dilute nitric acid (containing only about 5.4 per cent of HNO_3). After the solution was completed we added bullets made of pure antimony (the same that had been used in our previous experiments), and boiled the solution in an atmosphere of carbonic dioxide, using the same apparatus which we described in our previous paper (loc. cit.). After the reduction was ended, the solution was transferred to a flat-bottomed flask through a platinum tunnel, on which the bullets were retained; and, after washing into the flask the last traces of the solution, with as small an amount of hydrochloric acid as possible, the tunnel was removed, the bullets washed with water, and again weighed as at first on the platinum tunnel. In reducing the original solution, 0.4100 of a gramme of antimony were dissolved from the bullets. The solution now containing 1.4136 grammes of antimony was next exposed to the air for different successive periods of time in a room having a varying temperature of from 15° to 30°, sometimes in the shade, and at other times on a window seat, where the sun's direct rays fell on the flask during several hours of each clear day.

We give in the following table the weight of antimony dissolved from the bullets after each successive exposure to the air, the amounts in each case being determined with all the precautions described above, and still more at length in our former paper: —

Weight of Sb originally dissolved	. . . .	1.4136	
1. Dissolved from balls after 3 days' exposure,		0.0150	
2. " after 5 days	. . . .	0.0295	
3. " " 10 "	May 17 to May 27 .	0.0600	
4. " " 23 "	May 27 to June 19 .	0.1340	
5. " " 37 "	June 19 to July 26 .	0.2960	
6. " " 120 "	July 26 to Dec. 24 .	0.4481	0.9826

During these experiments the volume of the solution was gradually increased by the hydrochloric acid used in washing as above described, so that at last the volume amounted to 100 cubic centimetres.

It will be noticed that the amount of oxidation increased with the time of exposure, and that, so long as the amount was small, it was as nearly proportional to the time as could be expected under the varying conditions. The increased activity shown by determination No. 5 appeared to be due to the intensely warm weather and bright sunshine during the period, and the last determination would seem to indicate that, after the oxidation reached a certain limit, the process went on more slowly, as we should naturally expect; but, with the greatly varying conditions during this long period, no certain conclusion can be drawn in regard to the effect of any single cause.

The action we are discussing is entirely in harmony with the chemical relations of antimony. The most striking characteristic of this elementary substance is its tendency to form compounds of the radical antimonyl, SbO. The oxichlorides, the oxibromides, and the oxiiodides, whose relations we have discussed so fully in our previous papers, are examples in point, and we have been continually surprised by the appearance of such compounds in reactions in the most unexpected ways. In this respect antimony closely resembles vanadium, and with this element antimony is more closely allied than with its familiar associate, arsenic. What the precise reaction is in the present case we are not prepared to state. That it is not the simple conversion of a terchloride into a pentachloride we are convinced; but, in order to elucidate the subject, further investigations are necessary.

In this connection we may appropriately add that while the above determinations were in progress we repeated the experiment described on page 19 of our previous paper (loc. cit.). We treated in an open flask 5 grammes of finely powdered pure metallic antimony with 50 cubic centimetres of strong and pure hydrochloric acid, to which we added only one cubic centimetre of the very dilute nitric acid (5.4 per cent) described above. The flask was placed in a warm, protected place (30° C.), and shaken from time to time. Soon the acid became colored reddish-yellow, and the chemical action began. When it had apparently ceased, the contents of the flask were shaken together, and the solution became at once as colorless as water; but, on standing in the air, the color rapidly returned, spreading from the surface of the liquid downward. These phenomena were repeated again and again during four or five months, until the whole of the metal dissolved. According to the reaction usually assumed to take place under these circumstances, 5 grammes of metal would have required 50 cubic centimetres of acid, so that the effect was obtained with only one-fiftieth of the amount required by this theory.*

II. Argento-antimonious Tartrate (Silver Emetic).

On one occasion when analyzing antimonious chloride we noticed the formation of "silver emetic," and the observation led us to fear that this compound might be occluded by the argentic chloride or bromide, precipitated from a solution containing tartaric acid and antimony. This suspicion, thus excited, led us to make an investigation of the substance in question with the following results: —

As stated by us in our former paper, this compound was originally obtained by Wallquist by precipitating nitrate of silver with tartar-emetic, and was analyzed both by him and by Dumas and Piria. These chemists obtained respectively 27.31 and 28.05 per cent of oxide of silver. They appear, however, to have prepared the substance only in an amorphous form. As stated in the paper just cited, we first noticed the formation of crystals of the compound in a concentrated solution of antimonious chloride and tartaric acid, to which had been added an excess of argentic nitrate, and from the circumstances of their formation we were led to form a somewhat erroneous inference in regard to their relation to water. We find that the substance is far more soluble in this solvent than at first appeared. We have found from further investigation that one part of silver emetic dissolves completely in one hundred parts of boiling, and in somewhat less than five hundred parts of water at 15° C. In one determination made by evaporating, a saturated solution, which had stood a long time at a temperature of 15°, we found that one thousand parts of water had dissolved 2.76 parts and in another 2.68 parts of the salt. There

* Although in our synthesis of antimonious sulphide it was our constant study from the first to prevent the oxidation of the product, and although we most carefully guarded every phase of the process, yet the theory was advanced that the apparent weight of the product was *increased* by a partial oxidation of the antimonious sulphide at the temperature at which the red was converted to the gray modification. In answer to this wholly gratuitous assumption, it is only necessary to say: 1. That the oxidation of the dried precipitate at this stage of the process is a well-marked phenomenon, with every phase of which we are acquainted. 2. That the oxidation is always attended with a *loss* of weight. 3. That the products of our determinations were always examined, and have been in two cases preserved, and that these do not show the least signs of oxidation.

is obviously therefore no danger of the formation of this product in the precipitation of chlorine, bromine, or iodine from solutions of the antimony compounds of these elements in tartaric acid, unless the excess of silver nitrate is very large and the solutions very concentrated; and although we have most carefully looked for it in the precipitate we have never discovered it, except under the peculiar conditions described in our former paper, and our fear that it might be occluded by these precipitates was wholly unfounded.

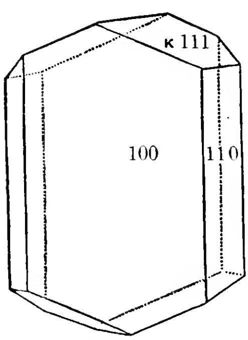
It is evident from the above experiments that the solubility of silver emetic in water like that of cream of tartar and other salts of tartaric acid is very greatly increased by heat, and we were easily able to obtain good crystals of the compound in large quantities by dissolving the precipitate, obtained as Wallquist describes, in boiling water, and allowing the solution to cool. The crystals are colorless and have a very brilliant, almost an adamantine, lustre.

From the reaction by which silver emetic is formed we should infer that the composition of the salt would be expressed by the symbol

$$Ag, SbO, H_2 \equiv O_4 \equiv (C_4H_2O_2) . H_2O.$$

This compound would theoretically contain 26.34 per cent of silver and, as a mean of three analyses, we obtained for the amount of silver in the crystals 26.30 per cent, as previously stated.

The crystals of silver emetic rapidly blacken in the light, and are very easily decomposed by heat. This decomposition takes place at about 200° C. with a slight explosion. A very fine carbon dust is blown out of the crucible, and a residue is left behind, which under the microscope is seen to consist of spangles of metallic silver mixed with an amorphous powder. Almost the whole of the powder dissolved easily in a solution of tartaric acid, and it evidently consisted of Sb_2O_3. In one experiment we weighed the silver emetic and the product, and found that 0.8460 gramme of the salt left 0.5304 gramme of residue. If the residue consisted solely of silver and Sb_2O_3, theory would require 0.5200 gramme, and it can be seen from this how perfect the decomposition was. It is obvious, therefore, that were this compound occluded as we at first feared, it would have made itself evident on drying the precipitates.



Mr. W. H. Melville, assistant in this laboratory, has made the following crystallographic measurements of the crystals whose formation and reactions we have described.

Angles between normals.

$$(111) \wedge (100) \quad 70^\circ \quad 19\tfrac{1}{3}'$$
$$(111) \wedge (\bar{1}\bar{1}1) \quad 70^\circ \quad 17'$$
$$a : b : c = 1 : 1.386 : 0.571$$

	I.	Measured.
100 ∧ 110	54° 12′	54° 19′
111 ∧ 110	51° 51′	51° 54′

The pinacoid planes were irregular and the angles can only be regarded as approximate.

System Trimetric with hemihedral habit.

Observed planes $+ \kappa$ {111} {100} {110} {011} ?

In the following table the crystallographic ratios are compared with those of the acid tartrates of rubidium, cæsium and potassium, formerly measured by us, and which have the same general form and hemihedral habit.

	Vertical.	Macro.	Brachy.
Acid tartrate of cæsium	0.661	1	0.694
" " rubidium	0.695	1	0.726
" " potassium	0.737	1	0.711
Silver emetic	0.412	1	0.721

III. On the Solubility of Argentic Chloride in Water.

In our analyses of antimonious chloride we constantly noticed, while washing the precipitated chloride of silver with warm water, that although the water first decanted from the precipitate was perfectly clear it became turbid when mixed with the successive washings; and on investigating the cause of this unexpected result we found that it was due to the chloride silver dissolved by the pure wash water and reprecipitated by the excess of nitrate of silver in the filtrate. As the solvent action of the water used for washing the precipitate evidently produced a marked effect on our chlorine determination, we determined at once to investigate the extent of the influence.

This subject has already been studied by Stas, whose observations are summed up by Dr. John Percy * in his recent volume on the Metallurgy of Silver in the following words: —

* Metallurgy of Silver and Gold, Part I. p. 60.

"The solubility of the chloride is greatest when in the flaky state, as precipitated in the cold from a sufficiently dilute solution of silver; the solubility diminishes as the flakes shrink when left to themselves, or as they are rendered pulverulent by long agitation with water. Flaky or pulverulent chloride of silver, dissolved in water, pure or acidified by nitric acid, is precipitated by the addition of a salt of silver, or of hydrochloric acid, or of an alkaline chloride. . . . The solution of the chloride is wholly effected by pure or acidified water, as the case may be, and is not caused by the soluble salt formed simultaneously with the chloride of silver. The presence of nitric acid in the water does not affect the solubility of flaky chloride of silver; but it increases the solubility of the pulverulent chloride in proportion to the quantity of acid present. The precipitation of the dissolved chloride is the exclusive result of its insolubility in the solution formed by adding an excess either of the silver salt or of the alkaline chloride."

So also in Liebig and Kopp, Jahresbericht, 1871, 339: "According to Stas, the granular scaly and crystalline chloride is wholly insoluble in cold water: in boiling water the solubility is comparatively great, but decreases rapidly with the temperature."

In our own investigation of this subject we have at once confirmed and extended these observations of Stas, and our results may be of interest as showing that in the very familiar method of determining chlorine by precipitation with nitrate of silver, which is generally supposed to be extremely accurate, a sensible error may arise from the solubility of the chloride of silver in the hot distilled water used in washing the precipitate. It would be well for every analyst to make the following very striking experiment, which will enable him to appreciate the extent of the action in question.

Take from five to ten cubic centimetres of pure hydrochloric acid, and precipitate the chlorine in the usual way with nitrate of silver, avoiding a large excess. After pouring off the supernatant liquid and washing the precipitate once or twice with cold distilled water, pour upon the white flaky chloride of silver a comparatively large volume of boiling water. As soon as the precipitate settles, pour off the clear hot water, dividing the solution between two precipitating jars. To one of these add a few drops of a solution of nitrate of silver, and to the other a few drops of hydrochloric acid. In both cases a precipitate of chloride of silver will fall, and most chemists, certainly, will be surprised at the effect; for it is not a mere turbidness that results, but a well-defined precipitate, whose amount is easily estimated. Successive portions of boiling water poured upon the precipitate give the same reaction. In one experiment the reaction was still preceptible in the fourteenth wash-water. But under the action of the boiling water, the precipitate becomes crystalline or granular and the action lessens, until at last the water does not dissolve sufficient chloride of silver to cause even a cloudiness on the addition of nitrate of silver, as just described. Mr. G. M. Hyams, a student in this laboratory, washed two different portions of chloride of silver with boiling water until the action ceased, and then weighed and examined the residue. In the first experiment 1.4561 grammes of chloride of silver were washed with 66 litres of water. The chloride of silver was then collected, and found to weigh 1.2320 grammes. Hence, 0.2241 gramme, corresponding to 15.39 per cent, had passed into solution. In the second experiment 60 litres of water were used, and 16.03 per cent of the chloride of silver originally precipitated were dissolved. These numbers, however, are only approximately accurate; for, as the precipitate becomes granular, it settles with less readiness, and there was necessarily some loss in filtering off so large a volume of liquid.

In the experiments above described the boiling water produced only a very slight decomposition of the chloride of silver. The precipitate, granulated by the washing, readily dissolved in aqua ammonia, leaving less than a milligramme of a black powder, which was proved to be metallic silver.

The solvent power of water on freshly precipitated chloride of silver did not appear to be influenced by the presence of free nitric acid, even in large quantities. We tried the effect both of dropping the nitric acid on the precipitate before pouring on hot water, and also of previously adding nitric acid to the boiling wash-water. We used amounts of nitric acid ($\delta = 1.355$) varying from five to two hundred cubic centimetres to the litre of water, but without finding any marked difference in the result.

The presence of a small amount of nitrate of silver in the water entirely prevented its solvent action, so far as we could discover. In order to determine the limit of the action, we added different quantities of nitrate of silver to the boiling water before pouring it on to the precipitated chloride of silver. With one centigramme of nitrate of silver to the litre of water, there was a marked turbidness on subsequently adding an excess of the same reagent to the filtrate. With two, three, or even four centigrammes to the litre, an opalescence could still be distinguished, although constantly diminishing with the increasing amount of the salt. With five centigrammes, there was no opalescence, and we concluded that one decigramme of nitrate of silver to the litre of boiling wash-water would certainly prevent all action.

A few drops of hydrochloric acid added to the wash-water greatly diminishes its solvent action on flaky chloride of silver, but does not wholly prevent it, as is evident from the fact shown in the table below, that hydrochloric acid does not precipitate chloride of silver from its solution in water nearly as effectually as nitrate of silver; and, as is well known, hydrochloric acid, if in any considerable excess, exerts a strong solvent action on the precipitated chloride.

As shown by Stas, the precipitation of chloride of silver, from its solution in hot water by the reagents we have named, depends solely on the change which the reagents produce in the solvent. That the action is an example of simple solution is shown by the fact that a considerable portion of the chloride of silver dissolved in boiling water is deposited when the solvent cools. This phenomenon is a striking one, and can easily be observed by pouring into a glass crystallizing pan some of the clear solution obtained in the experiment described above. As the water cools it becomes cloudy, and deposits a granular powder, which adheres to the bottom of the glass. The grains are usually very small; but if the solution cools slowly the crystalline form can readily be distinguished under the high powers of a good microscope, and the little cubes present all the characteristics of the native crystals of chloride of silver. It is evident, therefore, that the granular condition of chloride of silver is a crystalline condition, and this experiment may elucidate the manner in which the native crystals are produced.

We have thus far only spoken of the solubility of chloride of silver in boiling water. As is evident from the crystallization just described, the solubility rapidly diminishes as the temperature falls; but even at the ordinary temperature the solubility is distinctly marked. Lukewarm water poured on and off freshly precipitated chloride of silver, becomes decidedly opalescent on the addition of nitrate of silver, and even if cold water is used the opalescence is perceptible.

In order to obtain an approximate measure of the effects we have described, Mr. Hyams precipitated about fifteen grammes of chloride of silver, and, after thoroughly washing it, boiled the precipitate with a large volume of water in a glass flask. At the end of an hour he decanted through a filter about one litre of the boiling water, and, having divided the filtrate into two portions, he added to one portion nitrate of silver, and to the other, hydrochloric acid. The precipitated chloride of silver was in each case collected and weighed. At the end of two hours' boiling, two other portions were filtered off and treated in a similar way. These determinations were then repeated with a fresh quantity of chloride of silver, and afterwards taking a third quantity of chloride of silver, the boiling water was simply poured on twice in succession, and the similar portions thus obtained treated as before. The results in every case were nearly the same as shown in the following table. In this table

1 and 2 are results after one hour's boiling of 1st quantity.
3 and 4 " " " two hours' " " " "
5 and 6 " " " one hour's " " 2d quantity, etc.
7 and 8 " " " two hours' " " " " "
9 and 10 after simply pouring on boiling water.
10 and 12 " " " " " "

No.	Wght of Water.	Wght of AgCl.	Wght of AgCl per litre.	Precipitant.
1	523.6 gram.	0.0011	0.0021	Nitrate of silver.
2	469.5	0.0004	0.0009	Hydrochloric acid.
3	115.0	0.0002	0.0017	Nitrate of silver.
4	402.1	0.0004	0.0010	Hydrochloric acid.
5	225.0	0.0004	0.0018	Nitrate of silver.
6	462.0	0.0004	0.0009	Hydrochloric acid.
7	696.4	0.0014	0.0020	Nitrate of silver.
8	825.4	0.0007	0.0008	Hydrochloric acid.
9	700.4	0.0014	0.0020	Nitrate of silver.
10	747.2	0.0007	0.0009	Hydrochloric acid.
11	520.9	0.0011	0.0021	Nitrate of silver.
12	287.5	0.0003	0.0010	Hydrochloric acid.

If we assume that the amount of chloride of silver precipitated by nitrate of silver under the conditions described above is a correct measure of the solubility of the chloride, it appears from the above determinations that about two milligrammes of chloride of silver are dissolved by each litre of boiling water, and further that only about one half of the amount thus dissolved is precipitated by hydrochloric acid.

In making chlorine determinations, it is a very common practice to wash with very hot water, in order to secure the prompt settling of the chloride of silver, or to wash away any occluded material, and it was the chief object of this investigation to determine the extent to which the solubility of the chloride in distilled water might affect the result. For this purpose we made two series of determinations of the chlorine in chloride of antimony; in both cases precipitating with nitrate of silver the chlorine from a solution of the chloride of antimony in tartaric acid and water with the usual precautions. But, while in the first series the precipitated chloride of silver was washed with boiling hot distilled water to about the $\frac{1}{100,000}$ according to Bunsen's scheme; in the second series, although hot water was also used in washing, one decigramme of nitrate of silver per litre was added to each successive portion of the wash-water poured upon the precipitate, until the last two portions, which were poured on cold. By this simple device, the advantages of washing with hot water may be secured, while its solvent action is prevented. The results are given in the following table: —

First Series.

No.	Weight of $SbCl_3$ taken.	Weight of AgCl obtained.	Per cent of Cl calculated.
1	2.3856 gram.	4.4784 gram.	46.441
2	3.1300	5.8712	46.407
3	3.4207	6.4243	46.462
4	5.0031	9.3790	46.377
		Mean value,	46.422
		Max. diff. from mean,	0.047

Second Series.

No.	Weight of $SbCl_3$ taken.	Weight of AgCl obtained.	Per cent of Cl calculated.
1	3.4059 gram.	6.4188 gram.	46.624
2	3.6603	6.9014	46.643
3	2.4762	4.6658	46.617
4	2.5567	4.8212	46.651
		Mean value,	46.634
		Max. diff. from mean,	0.017
	Difference between means of two series,		0.212

It is evident from these results that when great accuracy is required, the solubility of chloride of silver may become a very serious source of error in determinations of chlorine, and in our first paper on the atomic weight of antimony, this was the chief cause of the discrepancy between the analyses of chloride of antimony on the one hand, and the bromide, iodide, and sulphide of antimony — analyses of which closely agreed among themselves — on the other hand. It was shown in the paper just referred to that, although the greatest care was taken in purifying the material, the chloride of antimony used actually left behind on evaporation a sufficient amount of oxichloride to reduce the per cent of chlorine 0.116 (loc. cit. page 64). The mean results which we actually obtained from seventeen analyses of chloride of antimony was 46.620; and when to this we add 0.212 and 0.116, the sum is 46.948, which differs from 46.985 — the theoretical value when Sb = 120, and Cl = 35.457 — by only 0.037, or if we take Cl = 35.5 by 0.072. In this estimate we leave out of the account the known solvent action on chloride of silver of the tartaric acid used to keep the antimony in solution. This must equally affect both of the series of determinations given above, and fully accounts for the small difference that remains to be explained. This whole discussion, however, only serves to confirm the conclusion previously expressed, that chloride of antimony is a most unsuitable material for the basis of an atomic weight determination; and, having explained the anomaly to which we gave prominence in a previous paper, we shall here take leave of the subject. We have also studied the solubility of bromide of silver in water, but this is so small that we found it difficult to measure the amount. In water at the ordinary temperature, or even in tepid water, bromide of silver is practically insoluble. In boiling water it is perceptibly soluble, but not more so than is chloride of silver in water at the ordinary temperature. Hence the determination of bromine does not require the same precautions, and is susceptible of greater accuracy than that of chlorine; and on this account, as well as for other reasons which we have previously discussed, the atomic weight of antimony can be deduced from the analyses of the bromide of antimony with as great accuracy as can at present be reached in such determinations. In the seven determinations of the per cent of bromine in bromide of antimony, whose results are given beyond (p. 18), the maximum difference from the mean value 66.6651 was only 0.0045, and Professor Mallet, in his analyses of bromide of aluminum, has obtained with the same method a similar degree of accuracy.*

In conclusion, we would again express our obligations to Mr. G. M. Hyams, who has assisted us in the work of this investigation.

IV. Additional Experiments on the Atomic Weight of Antimony.

In our previous paper on this subject, we gave our reasons for the opinion, since fully confirmed, that the bromide of antimony is the

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* Philosophical Transactions, Part III. 1880, 1022.

most suitable compound of this element, as yet known, for determining its atomic weight; and the results of fifteen analyses of five different preparations of the bromide were published, which gave for the atomic weight in question the mean value 120.00 with an extreme variation between 119.4 and 120.4 for all the fifteen analyses, and between 119.6 and 120.3 for the six determinations in which we placed most confidence. The antimonious bromide used in these determinations was purified first by fractional distillation, and secondly by crystallization from a solution in sulphide of carbon. In the crystallized product thus obtained, the bromine was determined gravimetrically as bromide of silver in the usual way. Although it seemed at the time that the results were as accordant as the analytical process would yield under the unfavorable conditions, which the presence of a large amount of tartaric acid in the solution of the bromide of antimony necessarily involved; yet it was obvious that the agreement was far from that which was desirable in the determination of an atomic weight, and our chief confidence in the accuracy of the mean value — independently of its remarkable agreement with previous results — was based on the fact that the known sources of error tended to balance each other. Hence our conclusions were stated with great caution, and the hope was expressed that, after a more thorough investigation of the subject, we might be able "to return to the problem with such definite knowledge of the relations involved as will enable us to obtain at once more sharp and decisive results than are now possible."

In our previous paper, we described a simple apparatus which we devised for subliming iodide of antimony; and in a note to the paper we stated that we were applying the same process to the preparation of bromide of antimony, and that it promised excellent results. Our expectations in this respect have been fully realized, and the product leaves nothing to be desired, either as regards the beauty or the constancy of the preparation. The fine acicular crystals are perfectly colorless, and have a most brilliant silky lustre. With ordinary precautions, they can be kept indefinitely without change, and it is easy therefore to determine the weight of the material analyzed to the tenth of a milligramme.

The material used in the following determinations was first prepared as described in our previous paper. It was then repeatedly distilled from a small glass retort rejecting at each distillation the first and the last portion. Lastly, it was twice sublimed in a slow current of absolutely dry carbonic dioxide. As it was only possible to sublime a few grammes at a time in the apparatus we used, and as the several products were not mixed, each of the portions analyzed was the yield of a separate sublimation, and the agreement of the results is therefore in itself a proof of the constancy of the preparation. In the first set of analyses, the bromine was determined gravimetrically by precipitation with nitrate of silver, as before described. The bromide of antimony was first dissolved in a concentrated solution of tartaric acid, using about five grammes of the crystallized acid to a gramme of the bromide, and the solution was then diluted with from 250 to 500 cubic centimetres of water. To this solution was slowly added, under constant agitation, a solution of nitrate of silver in slight excess of the amount required for complete precipitation. The amount of crystallized nitrate of silver required was always carefully weighed out, allowing one decigramme in excess of theory for every litre of the solution of bromide of antimony made as above described. The nitrate of silver was then dissolved in a considerable volume of water, and the bromide of silver was precipitated from a cold solution, care being taken to prevent the formation of lumps which invariably result if the solutions are warm or concentrated, and which greatly interfere with the washing of the precipitate. The precipitate was washed by decantation five times, pouring on in each case a volume of lukewarm distilled water equal to that of the original solution, and after the precipitate had settled, drawing off the wash-water with the inverse filter (see these Proceedings, Vol. XII. page 124.) Lastly, the precipitate was transferred to a porcelain crucible, and dried at from 120° to 130°.

The bromide of silver weighed was always tested, sometimes by dissolving the material in strong aqua ammonia, and at other times by heating it to the melting point. Had there been the least occlusion of silver emetic, or any other possible product, there would have been an insoluble residue or a loss of weight; and, since the bromide of silver always gave a perfectly clear solution, and the loss of weight on melting never exceeded a few tenths of a milligramme, we were assured that our product was perfectly pure.

Of the five determinations whose results are given below, the first three were made under my direction by Mr. G. De N. Hough; the last two were made with my own hands.

Analyses of Antimonious Bromide.

Determination of Bromine.

No.	Wt. of $SbBr_3$ taken in grammes.	Wt. of AgBr obtained.	Per cent of Br. Br = 80 Ag = 108.	Diff. from mean.	Value of Sb.	Diff. from mean.
1.	4.1767	6.5420	66.652	— 0.016	120.08	+ 0.08
2.	2.0250	3.1734	66.685	+ 0.007	119.90	— 0.10
3.	1.9999	3.1340	66.680	+ 0.012	119.93	— 0.07
4.	3.6985	5.7946	66.669	0.001	119.99	— 0.01
5.	2.8959	4.5361	66.653	0.015	120.08	+ 0.08
	Mean value		66.6679		119.996	
	Theory Sb. 120 requires		66.667			

The mean value of the percentage of bromine deduced from the fifteen analyses previously made (see these Proceedings, Vol. XII., page 54) was 66.666, which differs only by an inappreciable quantity from the mean of the above results. At the same time the results are much sharper, the maximum difference from the mean value having been reduced to less than one fifth of the previous amount, and to only 0.00025 of the quantity estimated, giving us with certainty the atomic weight of antimony within one one-thousandth of its value. It must be remembered, moreover, that, although these last results were obtained with the same compound as before, the material was prepared in a wholly different way. The material first used was purified by repeated crystallization from sulphide of carbon, — that last used by repeated fractional distillation and sublimation.

Hoping to reduce the limit of error to a still greater degree, we * were led to devise a volumetric method of testing the atomic weight of antimony, which, while it had all the advantages of the gravimetric method previously employed, is free from its sources of error. The method has also this great advantage, that it brings the question of the atomic weight of antimony down to a definite issue.

If the atomic weight of antimony were 122.00, it would require 1.7900 grammes of pure silver to precipitate the bromine from a solution of 2.0000 grammes of antimony bromide, while if the atomic weight of antimony were 120.00, it would require 1.8000 grammes of

* Since publishing our "preliminary notice," our attention has been called to the fact that a similar process was used by Professor J. W. Mallet of the University of Virginia in his investigation of the atomic weight of lithium, as it has since been used by him in his admirable work on the atomic weight of aluminum.

silver. Now it is easy to estimate volumetrically $\frac{1}{100}$ of this difference with certainty. We therefore prepared with great care a button of *pure** metallic silver, which we annealed, and rolled out to a thin ribbon. We then weighed out from two to four grammes of bromide of antimony, prepared by sublimation as described above, and dissolved this salt in an aqueous solution of tartaric acid, which we then transferred to a litre flask, and diluted to about 500 cubic centimetres. We next very accurately weighed out a quantity of silver slightly less than that which calculation showed was required for complete precipitation. This silver was dissolved in nitric acid, and the solution having been evaporated to dryness over a water bath, the silver salt was washed into the flask containing the bromide of antimony. As soon as the supernatant liquid had cleared, the small additional amount of a normal silver solution required to produce complete precipitation was run in from a burette, and measured with the usual precautions. We used no extraneous indicator, because it was important not to introduce any possibly new disturbing element into the experiment, and in the titration of bromine with silver, the normal and familiar phenomena, which mark the close of the process, furnish a very sharp indication. The details of one of the determinations were as follows: —

The weight of the bromide of antimony used amounted to 2.5032 grammes. To precipitate the bromine from the solution of this material, 2.2404 grammes of silver would be required if Sb = 122.00, and 2.2529

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* A quantity of silver which had been reduced from chloride and bromide of silver, obtained as a product of previous analytical processes, was dissolved in nitric acid, and precipitated as chloride by hydrochloric acid. The precipitate was first boiled in aqua regia, and then thoroughly washed, after which the chloride was reduced by boiling with caustic soda and inverted sugar, and the precipitate, again washed, having been transferred to a porcelain crucible and dried, was heated to a low red heat in a muffle until the grains were sintered together. The sintered mass was melted on a block of prepared coke before a gas blow-pipe, and while cooling was covered with a reducing flame in order to prevent the occlusion of oxygen gas. The metallic button was next rolled out into a ribbon between steel rollers; and, after the ribbon had been annealed in a muffle, the surface was etched with dilute nitric acid, and afterwards scoured with sand. The metal thus prepared was preserved under distilled water. The oxygen occluded by the metal thus prepared must have been, if any, exceedingly small in amount; but, even allowing the average quantity found by Dumas in metal which had been melted in the air under ordinary circumstances, we calculated that this amount would only affect the third decimal place in the atomic weight of antimony; and it seemed therefore unnecessary to take so inappreciable an effect into consideration. Moreover, the great purity of our material was subsequently made evident.

if Sb = 120.00. We weighed out, with as much accuracy as if we were adjusting a weight, the smaller of these two quantities of metallic silver, and after dissolving the pure metal in pure nitric acid, evaporating the solution to dryness, and redissolving in water, we gradually added the whole of this silver solution to the litre flask containing the solution of bromide of antimony, in the manner described above. It was then found that $12\frac{4}{10}$ cubic centimetres of a standard silver solution (one gramme of silver to the litre) were required to complete the precipitation. It will be seen that the weights of the bromide of antimony and silver used could be thus determined with the most absolute precision, and we have the greatest confidence in these values to the $\frac{1}{10}$ of a milligramme. Moreover, it will be noticed that the volumetric method is only used to estimate the difference in the atomic weight which has been in question, and that, if the method were only accurate to the $\frac{1}{10}$ of the quantity to be measured, it would give us the value of the atomic weight within $\frac{2}{10}$ of a unit, while if, as we had reason to believe, the process was accurate within one per cent, it would fix the atomic weight within $\frac{2}{100}$ of a unit.

By the method just described, the following results were obtained. The letters *a* and *b* indicate different preparations: —

	Wt. of $SbBr_3$ taken.	Total Wt. of Ag used.	Per cent of Br Ag = 108 Br = 80.	Corresponding value of Sb.
a 1.	2.5032	2.2528	66.6643	120.01
a 2.	2.0567	1.8509	66.6620	120.02
a 3.	2.6512	2.3860	66.6644	120.01
b 4.	3.3053	2.9749	66.6696	119.98
b 5.	2.7495	2.4745	66.6653	120.01
	Mean value,		66.6651	120.01
	Theory Sb. 120 requires		66.6666	
	" Sb. 122 "		66.2983	

The extreme variation from the mean in these determinations is less than one ten-thousandth of the quantity directly estimated, and corresponds to less than two ten-thousandths of the total value in the atomic weight of antimony. We have thus reached the extreme limit of accuracy with determinations on this scale. By using very much larger amounts of material, it is possible that we might still further diminish the limits of experimental error; but when we consider the further causes of error incident to handling so large an amount of material, it seems doubtful whether any advantage would really be gained. At all events such determinations would require an expenditure of labor and skill which is not demanded in the present condition of chemistry.

While making the first three volumetric determinations, it became obvious that the mode of experimenting was highly favorable to the accurate estimation of the amount of bromide of silver formed; and, were we to repeat this investigation, we should adopt the same mode of precipitating bromine in all cases. The rotatory motion given to the liquid mass in the stoppered flask in order to hasten the "clearing up," after each fresh addition of the silver solution, tends very greatly to granulate and thoroughly wash the precipitate. In the last two determinations, therefore, we collected and weighed the bromide of silver formed, and this weight gave us a most important control over the whole work. In the previous work we assume that the ratio of Ag : Br = 108 : 80, and find that on this assumption Br : Sb = 80 : 120. But if we both determine the amount of silver required to precipitate a given weight of antimonious bromide, and also at the same time the weight of argentic bromide formed, it is obvious that we fix at once the ratio of three atomic weights (Ag : Br : Sb) independently of any assumption whatsoever. This, so far as we know, is a new feature in investigations of this kind, and evidently vastly diminishes the possibilities of error, and enhances the value of the result. We give in full the two determinations which were made in this way:—

No. 1.

Weight of tube and $SbBr_3$	22.2225	grammes.
" after transfer to flask	18.9172	"
" of $SbBr_3$ taken	3.3053	"
" of silver taken	2.9749	"
Weight of crucible and filter	44.3729	"
" " " with AgBr dried at 150°	49.5512	"
" " " after again heating	49.5512	"
" " AgBr dried at 150°	5.1783	"
Weight of crucible and AgBr after removing small filter with adhering particles	49.5008	"
Weight after heating AgBr. to incipient fusion	49.5007	"
Reduced weight of AgBr	5.1782	"
Per cent of bromine	66.665	"
Atomic weight of antimony	120.01	"

No. 2.

Weight of tube and $SbBr_3$	32.4979	grammes.
" after transfer to flask	29.7484	"
" of $SbBr_3$ taken	2.7495	"
" cf silver taken	2.4745	"
" of crucible and filter	44.3732	"
" " " with AgBr dried at 150° . .	48.6810	"
" " " after again heating	48.6810	"
" " AgBr dried at 150°	4.3078	"
Weight of crucible and AgBr after removing small filter with adhering particles . . .	48.5524	"
Weight after heating AgBr to incipient fusion .	48.5522	"
Reduced weight of AgBr	4.3076	"
Per cent of bromine	66.667	"
Atomic weight of antimony	120.00	"

Bringing now these results together, we have two additional gravimetric determinations of the atomic weight of antimony.

Weight of $SbBr_3$ taken.	Weight of AgBr determined.	Per cent of Bromine Ag = 108 Br = 80.	Corresponding value of Sb.
b 6. 3.3053	5.1782	66.665	120.01
b 7. 2.7495	4.3076	66.667	120.00
Mean value,		66.666	120.00

It is now obvious that these gravimetric determinations, taken in connection with the corresponding volumetric results, give us the most conclusive evidence of the purity, both of the metallic silver used, and also of the bromine in the bromide of antimony, which is the basis of this atomic weight investigation. By comparing *b* 6 and *b* 7 with *b* 4 and *b* 5 respectively, we obtain the following data: —

1. 2.9749 grammes of silver gave 5.1782 grammes bromide of silver.
2. 2.4745 " " " 4.3076 " " "

Hence it follows that, as shown by these experiments, the proportions of the silver to the bromine were respectively: —

	1. 108.00	silver to	79.99 bromine.
	2. 108.00	" "	80.01 "
Mean value	108.00	" "	80.00 "

This is the ratio of the atomic weight of silver to that of bromine, and corresponds to the second decimal place with the determinations of Stas as well as with those of Dumas.

We have now furnished as evidence of the atomic weight of antimony, —

1. The mean of fifteen analyses of bromide of antimony purified by crystallization from sulphide of carbon, with an extreme variation between 119.4 and 120.4 for all the fifteen analyses.

2. The mean of five analyses of bromide of antimony purified by distillation and sublimation, with an extreme variation between 119.90 and 120.08.

3. The mean of five volumetric analyses of bromide of antimony, also purified by distillation and sublimation, with an extreme variation between 119.98 and 120.02.

4. Two gravimetric determinations of the bromine in two of the portions of bromide of antimony used in the volumetric analyses, but still essentially distinct determinations, which gave almost identical results.

Bringing these several means together as of equal value, we have :—

	Per cent of Br.	Value of Sb.
1. Mean of fifteen determinations	66.666	120.00
2. " five "	66.668	119.99
3. " five "	66.665	120.01
4. " two "	66.666	120.00
Final mean value,	66.666 +	120.00

Furthermore, we have shown by the last two determinations, that the ratio of the atomic weight of the silver to that of the bromine, used in our experiments, was 108.00 to 80.00, and hence that the ratio of the atomic weights of bromine silver and antimony must be

$$Ag : Br : Sb = 108.00 : 80.00 : 120.00,$$

with a probable error not exceeding 0.01 in any case. Of course our experiments only serve to fix the ratio between these three quantities, and any considerations which may lead chemists to change the value of one of the quantities must affect the other two in the same proportion. If with Stas we take $Ag = 107.66$, then $Br = 79.75$, and $Sb = 119.63$; and in this connection the fact should be recalled that the ratio of Ag to Br, according to Stas, is essentially identical with that given above, and the same as that found both by Dumas and by Marignac. Of all the ratios between the atomic weights, it is the one in regard to which there is the greatest certainty; and it is with this very well established relation that we have connected the atomic weight of antimony.

Entirely in harmony with the above results are our experiments on the synthesis of sulphide of antimony, in which we found as a mean of thirteen experiments Sb = 119.94 when S = 32; and the same is equally true of our analyses of iodide of antimony, which gave as a mean of seven determinations Sb = 119.98 when I = 127.00. But although these results formed important stages in our investigation, they now add but little to the evidence of the far more accordant results since obtained. When compared with these later results they show, however, to what a great extent error may be eliminated by the repetitions of an imperfect process.

Lastly the anomaly which the analysis of antimonious chloride first presented has been explained by finding, first, that the material employed contained a constant amount of oxichloride; and, secondly, that the water used in washing the precipitate exerted a definite solvent action on the chloride of silver estimated.

Having thus solved the problem we undertook as far as is at present practicable, we must now take leave of the subject, regretting only that our investigation should have been the occasion of any controversy. In addition to the recognition we made in our previous paper, we would here express our obligations to Mr. G. De N. Hough and Mr. G. M. Hyams, who have greatly aided us in the experimental work during the latter part of this investigation.

V. — The Boiling Point of Iodide of Antimony, and a New Form of Air Thermometer.

In continuation of our investigations on the Haloid Compounds of Antimony, the boiling point of antimonious iodide has been determined by Mr. W. Z. Bennett, at the time a student in this laboratory. The observations were made with Regnault's air thermometer, but it was found possible to simplify very greatly the details of the process without seriously impairing the accuracy of the result. For temperatures above the range of a mercury thermometer's measurements, accurate to one degree centigrade, are all that the uncertain conditions of most problems permit, and all, therefore, that the circumstances demand. As used by Regnault, the air thermometer is capable of measuring such temperatures accurately to the one tenth of a degree, and by multiplying observations possibly to the one hundredth of a degree. In his admirable investigation of the boiling point of sulphur at different temperatures, the observations of temperature are undoubtedly accurate to this extent; but Regnault's own discussion of these observations plainly indicates that there must have been unknown or accidental causes influencing his experiments, which render the results uncertain to at least one degree; and the boiling point of sulphur is still in doubt to this extent. It should be added, however that there are only a very few boiling points which are known more accurately; for, even when within the range of a mercury thermometer, an observation of a boiling point, to be accurate to a tenth of a centigrade degree, requires an attention to circumstances which is seldom bestowed on such observations.

The glass thermometer-bulb used in our experiments is represented in the accompanying figure (Fig. 1) of one half the actual size in its linear dimensions. The longer stem was made of thermometer tube, and a shorter stem was added to the opposite end of the bulb in order to facilitate the cleaning, drying, filling, or emptying of the interior, all of which was easily accomplished by the aid of a Bunsen pump. The shorter stem was of course sealed after the bulb had been dried and made ready for use, and before it was immersed in the medium whose temperature was to be measured. After an equilibrium had been established at this unknown temperature, T'°, the protruding end of the longer stem was sealed, and at the same time the height of the barometer, H, was noted. The bulb was then taken to a room of uniform temperature provided in the laboratory for gas analysis, and, after being mounted on a convenient support, the end of the stem was broken off under mercury, and the apparatus left to itself for a time to secure a perfect equilibrium of temperature. This temperature, T°, was then observed, by means of a standard thermometer hanging near the bulb; also the height, h, to which the mercury had risen in the bulb, was measured by a cathetometer; and in addition the height, H', of a barometer (hanging in the same room) was noted. Closing now the open stem with the finger, the bulb was quickly inverted and the containing mercury drawn out into a tarred vessel and weighed (nipping off the extreme end of the shorter stem for the purpose). This gave the weight, w. Lastly, the bulb and stem having

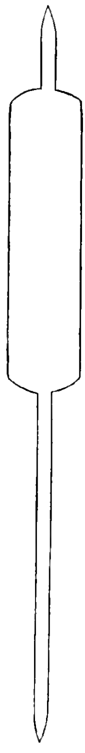


Fig. 1.

been completely filled with mercury by suction, the weight W, corresponding to their total capacity was obtained in a similar way. The required temperature could now be calculated by means of the well-known law of Charles: —

$$T^{\circ\prime} + 273^{\circ}.2 = (T^{\circ}. + 273^{\circ}.2)\ \frac{W}{W - w} \cdot \frac{H}{H' - h}\ [1 + (T^{\circ} - T^{\circ\prime})\ k]$$

It will be noted that as the mercury columns, including the heights of the barometer, were all measured at the same constant temperature; and, as we are dealing with relative values only, no reductions are necessary. Moreover, an error of one tenth of a millimetre in the value of $\frac{H}{H' - h}$ would make, in determining the boiling point of sulphur (448°), a difference of only one eighth of a degree, so that measurements of these heights are sufficiently close, if accurate, to one half a millimetre, and might even be made with a common rule. The most uncertain element in the formula is the expansion of glass; but if the bulbs are made of flint glass (lead glass) tubing, such as is used in this neighborhood for ornamental ware, the mean coefficient of expansion will vary very little from 0.000025, if the temperature does not exceed that at which the glass begins to soften. The rate of expansion of flint glass is not only less than that of crown, but it is also more constant, and increases very slowly with the temperature. Flint glass is therefore better adapted for the use we are describing. The expansion of the glass used in our experiments was carefully determined, and found to have the value given above, within two or three tenths of a unit in the last place. A difference of one unit in this place would make a difference of one third of a degree in the boiling point of sulphur.

In order to test the accuracy of this method, Mr. Bennett made four determinations of the boiling point of sulphur under different barometric conditions, which in the following table are compared with the results of Regnault, reduced to the corresponding pressures: —

Barometer. Height at 0°.	Boiling Point of Sulphur. Bennett.	Regnault.	Diff.
758.8	447.4	447.3	+ 0.1
763.9	448.2	447.7	+ 0.5
769.6	448.2	448.1	+ 0.1
776.7	448.2	448.7	— 0.5

Regnault made eight observations on the maximum tension of sulphur vapor at temperatures varying from 387°.64 to 554°.03, and from a discussion of these deduced the constants of an exponential formula, by which he calculated a table of maximum tensions for every ten degrees between the extreme limits, and also plotted a corresponding curve. It so happens, however, that the only two observations within the range of ordinary atmospheric pressure fall outside, and on the same side, of this assumed curve. These observations are the ones usually taken as indicating the boiling point of sulphur; and Victor Meyer, in one of his methods of determining the density of the vapors of substances which have a high boiling point, assumes a value for the boiling point of sulphur (at the mean atmospheric pressure at Zurich), which he obtains by simple interpolation from the two observations just referred to.* In like manner we have calculated the above values corresponding to the pressures at which Mr. Bennett's results were obtained on the basis of the same two observations; but, instead of simply interpolating by the first differences, we have assumed that the variation between the two observed values would follow the law indicated by the general curve, which Regnault gives as the best expression for all his observations. But according as we take the two observations, or the whole, we obtain values for the boiling point of sulphur differing by more than a degree; and hence, as we have already said, there is still an uncertainty in regard to the boiling point to this extent. As is evident, Mr. Bennett's observations confirm very closely the interpretation of Regnault's results, adopted by both Victor Meyer and by ourselves.

After the accuracy of our method had been thus placed beyond doubt within the limits required, Mr. Bennett made three determinations of the boiling point of antimonious iodide, with the following results: —

Barometer. Height at 0°.	Boiling Point of SbI_3.
758.1 millimetres.	400°.4
758.4 "	400°.9
759.3 "	400°.9

Probably only a small part of the difference between these observa tions depends on the variations of pressure. We only regard the method as accurate to whole degrees, and 401° is evidently the boiling

* Fresenius's Zeitschrift, xvi. 482.

point of antimonious iodide at the normal pressure of the air within half a degree on either side.

The method we have here described we can most confidently recommend as a most efficient and accurate means of determining high temperatures in chemical laboratories. It requires no expensive apparatus, and no more delicate manipulation than most processes of gas analysis. Indeed, this method is most readily associated with Bunsen's methods of gas analysis; and, in a laboratory provided with a room fitted for that work, the observation of temperature we have described can be made in a very short time.

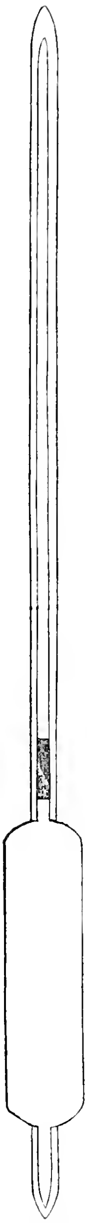


Fig. 2.

In connection with these experiments, we were led to devise a very simple and inexpensive form of differential air thermometer, that can be used almost as readily as a mercury thermometer, and which will measure either high or low temperatures with all the accuracy that is usually required. The instrument is represented by Fig. 2 of one half its linear dimensions. The long stem is made of "barometer tubing," a little over a millimetre in diameter, and by careful calibration is arbitrarily divided into parts of equal capacity, making, we will say, two hundred divisions on the length of the stem. While the instrument is still open at both ends it is easy to determine, first, the weight of mercury which fills the bulb up to the first division of the stem; and secondly, the weight of a column of mercury covering an observed number of divisions of the stem. These constants being known, and the interior of the instrument having been most carefully dried, for which the two openings offer great facilities, a short column of very pure mercury is introduced, and brought into the position represented in the figure. The two ends are now hermetically closed with a blow-pipe, and the instrument is made. It can be used either in a vertical or horizontal position, although the zero point of the scale is slightly different in the two cases, owing to the weight of the short mercury column. Of course this column remains immovable so long as the temperature of the two ends remains the same; but when the bulb is heated, the column, which we will call the index, moves up the stem, which becomes a closed monometer. If the instrument is to be used for measuring low temperatures, the index should be placed about one third way up the stem before closing the open ends. The theory of the instrument is the same in either case, but in our description we will assume that the index has been set for measuring high temperatures, as shown in our figure.

As the instrument is a differential thermometer, its accuracy depends on keeping the stem at a *constant* and *known* temperature; and from this constant temperature the observed temperatures are deduced. When the thermometer is held in a horizontal position, and the stem can be protected from the neighboring sources of heat, it is sufficient to place a standard mercury thermometer at the side of the stem; but it is always better, and generally necessary, when the stem is in a vertical position over the source of heat, to surround the stem with a jacket, through which circulates a stream of water of known temperature. This temperature we will call the temperature of reference, and represent by $T°$. In order now to determine the value in centigrade degrees of the division of the instrument, we place it in the position in which we propose to use it; and when the two ends are at the same temperature, we observe the position of the two ends of the index on the graduate scale. We can now easily find from the weights obtained before closing the instrument, first the weight of mercury which would fill the bulb and stem up to the index, which we call W; and, secondly, the small weight of mercury which would fill one division of the stem which we will call w. We have also, by observation, the number of division on the stem above the index. This number, which we count from the closed end of the stem, we will represent by N.

Assume now that the bulb and stem up to the index is immersed in a medium which has the temperature, T'. The index moves, and in its new position let N' represent the number of division on the stem above the index. We can now easily deduce the following values: —

$\frac{N}{N'}$ = the ratio of the tension of the confined air at $T'°$ and $T°$.

$N - N'$ = the number of division through which the index moved.

$\frac{W + (N - N')\,w}{W}$ = the ratio of the volumes of the air in the bulb at $T°$ and $T'°$, independent of the expansion of the glass.

$\frac{W + (N - N')\,w}{W}\,(1 + [T - T']\,k)$ = same ratio, allowing for expansion of glass.

Then, as we can easily deduce from the laws of Mariotte and Charles: —

$$T'^{\circ} + 273 = \frac{N}{N'} (T^{\circ} + 273) \frac{W + (N - N')\, w}{W} (1 + [T^{\circ} - T'^{\circ}]\, k)$$

With this formula, it is now easy to compute the values for each division of our arbitrary scale. We cannot, however, depend absolutely on the result, as there are several causes which will differ with each instrument, and of which we can take no account. It is therefore best to observe, with the instrument, two or three well-established boiling points, which will give us fixed points by which we can correct the table, and we shall then have an instrument whose precision is fully equal to that of a mercury thermometer.

It is, of course, very desirable that the temperature of reference T° should be always the same and as invariable as possible. This is best accomplished, as above suggested, by maintaining a circulation of water through a glass jacket surrounding the stem of the instrument and enclosing also a small mercury thermometer, which is best tied to the stem. By selecting the temperature of reference a little higher than the highest temperature of the water supplied by the laboratory hydrants, it is easy to maintain the required temperature within a degree by regulating the flow. The instrument may then be adjusted to the tubulature of a retort and used in fractional distillations.

VI. Revision of the Atomic Weight of Cadmium.

By Oliver W. Huntington, *of the Senior Class.*

The method adopted by Professor Cooke for verifying the value of the atomic weight of antimony, described in this volume (page 16), proved to be so definite and conclusive, that it seemed desirable to apply it in all other cases to which it was suited, in order not only to verify the received values of the atomic weights, but also to test more fully the hypothesis of Prout, an hypothesis to which recent investigation and speculations have given renewed interest.*

The method of Professor Cooke is applicable to all those elements of which a pure, stable, well-defined, and soluble bromide can be pre-

* See Revision of the Atomic Weight of Aluminum, by J. W. Mallet, Philosophical Transactions, part iii. 1880: also various papers by J. Norman Lockyer on the disassociation of the chemical elements in "Nature" and in the Proceedings of Royal Society; also Cooke's Chemical Philosophy, revised edition, page 272.

pared. It consists in determining in one series of analyses the bromine of the compound as bromide of silver by the usual gravimetric method with the precautions already described (page 19); and in another series of experiments, or in the same analyses, when practicable, determining the amount of silver required to precipitate the bromine. We thus obtain not only the relation of the atomic weight sought both to that of bromine and to that of silver; but also the relation between the atomic weight of bromine and that of silver; and since all experimenters agree on this last ratio to within one ten-thousandth of its value it is evident that the comparison of the two series of results gives a sharp control of the accuracy of the work.

Professor Cooke assigned to me the atomic weight of cadmium as my portion of the work he had planned on the revision of the atomic weights, and this investigation was made with his aid and under his immediate direction. Bromide of cadmium fulfils all the conditions which the new method requires; and, since the accepted value of the atomic weight of cadmium is a whole number, it seemed probable that a revision of this value by a more exact process would bring additional evidence in support of the hypothesis of Prout.

Having found that bromide of cadmium could not readily be purified by repeated crystallizations on account of its very great solubility in water, we sought to obtain a pure compound by preparing pure carbonate of cadmium on the one hand and pure hydrobromic acid on the other.

To prepare pure carbonate of cadmium the commercial metal was first dissolved in pure hydrochloric acid. From this solution, still strongly acid, sulphide of cadmium was precipitated by sulphide of hydrogen, and the precipitate thoroughly washed with hot distilled water. The sulphide having been redissolved in hydrochloric acid, and the resulting sulphide of hydrogen expelled by boiling, the cadmium was next precipitated as carbonate by carbonate of ammonia, and the precipitate digested with a large excess of this reagent. The white carbonate thus obtained was thoroughly washed and redissolved in hydrochloric acid; and the same series of precipitations repeated. Lastly, in order to remove any possible trace of adhering chloride, the carbonate of cadmium which had thus been twice precipitated by carbonate of ammonia, and twice digested with a large excess of this reagent, was dissolved in pure hydrobromic acid, and a third time precipitated and digested with pure carbonate of ammonia.

The hydrobromic acid used in this investigation was made by the process described by Dr. Edward R. Squibb, of Brooklyn, in the

Transactions of the Medical Society of the State of New York.* In order to purify the acid, it was repeatedly redistilled with a small amount of a concentrated solution of bromide of potassium, rejecting each time the distillate until the boiling point rose to 128°; when, as is well known, an acid containing about 47 per cent of HBr distils unchanged. The acid thus obtained was as colorless as water.

Meanwhile, in order to test the purity of the hydrobromic acid and also as a basis for the rest of our investigation, we prepared a quantity of pure silver by the method already fully described in a previous part of this volume (page 17); and with the pure silver thus prepared the following two sets of determinations were made.

For the first set, weighed amounts of silver were dissolved in very carefully purified nitric acid, using only a very slight excess of this solvent in any case. We prepared for the purpose a dilute acid by mixing one part of acid, having Sp. Gr. 1.355, with four parts of water and of this weak acid 5.3 $\overline{c.\,m.}^3$ were required for each gramme of silver. We were thus able to estimate the amount necessary for each analysis, and we used generally one half a cubic centimetre in excess.

The silver having been perfectly dissolved, and the solution diluted with water to from two hundred to five hundred cubic centimetres, according to the amount of silver used, we gradually and cautiously precipitated bromide of silver by adding pure hydrobromic acid, prepared as just described, but greatly diluted until the acid was very slightly in excess. For the method of washing and collecting this

---

* "The formula and process for making an acid of this strength are as follows: —

Take of Potassium Bromide	Six parts.
Sulphuric Acid, Sp. Gr. at 15°.6 C. 1.838, at 25° C. 1.828 . . .	Seven parts.
Water	Nine parts.

"Add to the sulphuric acid one part of the water and cool the mixture. Then dissolve the potassium bromide in six parts of the water by means of heat, supplying the loss of water by evaporation during the heating. Pour the diluted sulphuric acid slowly into the hot solution with constant stirring, and set the mixture aside for twenty-four hours, that the sulphate of potassium may crystallize. Pour off the liquid into a retort, break up the crystalline mass, transfer it to a funnel, and, having drained the crystals, drop slowly upon them two parts of the water so as to displace and wash out the acid liquid. Add the liquid, thus drained off and washed out, to that in the retort, and distil the whole nearly to dryness, or until nothing further distils off by moderate heating. The distillate will weigh about ten parts and should contain about thirty-seven per cent of hydrobromic acid."

precipitate, we may refer to Vol. XII. page 121, of these Proceedings. The results were as follows: —

	Weight of Silver.	Weight of Bromide of Silver.	Per Cent of Silver.
1.	1.4852 grammes.	2.5855 grammes.	57.444
2.	1.4080 "	2.4510 "	57.446
3.	1.4449 "	2.5150 "	57.451
		Mean Value	57.447

For the second set of experiments bromide of silver precipitated, washed, and dried as described (loc. cit.), was melted in a platinum crucible, and then reduced by a voltaic battery under dilute sulphuric acid. This process was devised and perfected by Mr. L. P. Kinnicutt, Assistant in this Laboratory, who had the great kindness to conduct the reduction in the following determinations.

	Weight of Bromide of Silver.	Weight of Silver.	Per Cent of Silver.
1.	4.1450 grammes.	2.3817 grammes.	57.444
2.	1.8172 "	1.0437 "	57.434
3.	4.9601 "	2.8497 "	57.449
		Mean Value	57.442

These results show conclusively the great accuracy of Mr. Kinnicutt's process, which he will describe in detail in another place. The mean of the two sets of results gives for the per cent of silver 57.445, the theoretical per cent ($Ag = 108$ and $Br = 80$) being 57.446. If we throw out No. 2 of second series, which is obviously less trustworthy than the other two determinations of the same series, on account of the comparatively small amount of material used, the mean of the remaining five determinations corresponds absolutely to theory, and the total result, therefore, leaves no doubt whatever as to the absolute purity of the materials employed.

Bromide of cadmium was now prepared by dissolving pure carbonate of cadmium in pure hydrobromic acid, and subliming the product previously dried at 200° in a current of pure and perfectly dry carbonic dioxide gas. The carbonic dioxide was prepared by mixing bicarbonate of soda and sulphuric acid with a large volume of water in a strong generator, and drawing off the gas under pressure through appropriate washers and driers; and the apparatus used for subliming the bromide of cadmium was similar to that described in these Proceedings, Vol. XIII. page 57, using however a porcelain tube heated by a gas furnace in place of a tube of glass. The bromide of cadmium when thus sublimed crystallizes in pearly scales around the open mouth of the tube.

Prepared as we have described, anhydrous bromide of cadmium is a splendid preparation. The precise form of the highly lustrous crystals could not be distinguished, but the scales are tabular crystals having a single optical axis normal to the extended face of the scales and having a high negative double refracting power. Although so soluble, the crystals are not sensibly hygroscopic, and can be weighed on an open watch-glass without the slightest variation of weight during the process. They dissolve at once in water without leaving a trace of residue.

The following determinations were all made with the material we have described, and since only a few grammes could be sublimed at a time, the separate analyses were made with the products of nearly as many sublimations. Some of the material was sublimed twice, and the constancy of the composition under these circumstances is the best proof possible of the definiteness of the compound. The results of the analyses may be classed under two heads.

In one series of determinations, the bromide of antimony, whose weight had been accurately determined, having been dissolved in pure water in a stoppered flask, a little less than the calculated amount of silver required to precipitate the bromide was carefully weighed out and dissolved in a measured amount of weak nitric acid allowing as before described a slight excess. This solution properly diluted was then gradually added to the solution of bromide of cadmium under constant agitation in order to avoid the aggregation of the bromide of silver in lumps. The agitation was frequently renewed until the precipitate settled, and then a standard solution of silver (one gramme to the litre) was cautiously added until the precipitation was complete, and the last drops did not produce the faintest opalescence after standing. The precipitate was now washed by decantation five times successively, using each time a volume of cold distilled water equal to the volume of the original solution, and pouring off the water into a porcelain crucible, from which it was drawn by the reverse filter. Finally, the precipitate was washed into the crucible, and after drying at from 120° to 130° weighed with the small filter.

In a second series, the determinations were conducted in the same way as in the first, excepting that the chief attention was directed to determining the exact point of complete precipitation. In several cases, indicated by an asterisk, both the amount of silver required, and the amount of argentic bromide formed were determined in the same experiment; but this was not always practicable.

FIRST SERIES.

	Weight of Bromide of Cadmium.	Weight of Bromide of Silver found.	Value of Cd when Ag = 108 and Br = 80
1.	1.5592 grammes.	2.1529 grammes.	112.32
2.*	3.7456 "	5.1724 "	112.28
3.	2.4267 "	3.3511 "	112.28
4.*	3.6645 "	5.0590 "	112.36
5.*	3.7679 "	5.2016 "	112.36
6.	2.7938 "	3.8583 "	112.27
7.*	1.9225 "	2.6552 "	112.26
8.	3.4473 "	4.7593 "	112.34
		Mean Value	112.31

SECOND SERIES.

	Weight of Bromide of Cadmium.	Weight of Silver required.	Value of Cd when Ag = 108 and Br = 80
1.*	3.7456 grammes.	2.9715 grammes.	112.27
2.	5.0270 "	3.9874 "	112.30
3.*	3.6645 "	2.9073 "	112.26
4.*	3.7679 "	2.9888 "	112.30
5.*	1.9225 "	1.5248 "	112.33
6.	2.9101 "	2.3079 "	112.35
7.	3.6510 "	2.8951 "	112.39
8.	3.9782 "	3.1551 "	112.35
		Mean Value	112.32

As can easily be calculated according to the mean of the first series of determinations, 1.0000 gramme of bromide of cadmium gives 1.3808 grammes of argentic bromide, and according to the mean of the second series 1.0000 gramme of bromide of cadmium requires for complete precipitation 0.7932 gramme of silver. Hence, as a mean of these experiments, 0.7932 gramme of silver yields 1.3808 grammes of argentic bromide and therefore corresponds to 0.5876 gramme of bromine. Moreover, since

$$0.7932 : 0.5876 = 108.000 : 80.006,$$

it follows with a very high degree of probability that

$$Ag : Br : Cd = 108.00 : 80.00 : 112.31,$$

within one ten-thousandth of the value of either quantity. It must of course be regarded as absolutely proved that, in the material analyzed, the proportion of bromine to the remainder of the mass, assumed to be pure cadmium, is as 2×80.00 to 112.31, but it is always conceivable that the material used contained some unknown impurity. In the present case, however, such an assumption is highly improbable; first, because such extreme care was taken in the preparation; secondly, because the products of the different sublimations were so constant in composition; and, thirdly, because the presence of any of the metals usually associated with cadmium would tend to lower and not to raise the apparent atomic weight. If any impurity is present, it would seem as if it must be some unknown element, and only on such a bare chance as this can the evidence be invalidated which the results of this investigation furnish against the hypothesis of Prout.

INVESTIGATIONS ON LIGHT AND HEAT, PUBLISHED WITH AN APPROPRIATION FROM THE RUMFORD FUND.

II.

CONTRIBUTION FROM THE PHYSICAL LABORATORY OF HARVARD COLLEGE.

ON THE SPECTRUM OF ARSENIC.

BY OLIVER W. HUNTINGTON.

Presented by Professor Trowbridge, June 28, 1881.

IT has been noticed in the case of the spectrum of nitrogen gas, that the spectrum obtained from an electric discharge of low intensity through a rarified atmosphere differs from that obtained when the intensity of the discharge has been increased by a Leyden jar. In the case of the low tension discharge, the bands of the spectrum appear fluted on the more refrangible side; but upon the introduction of a Leyden jar into the circuit the fluted appearance at once vanishes, and the spectrum breaks up into isolated bands. This difference has been ascribed to a difference of condensation of the molecule. Now as arsenic is allied to nitrogen, it was thought the same difference might appear in the spectrum of arsenic, and we proposed to make this a subject of investigation. For this purpose, we first prepared two tubes, — one an ordinary Geisler tube, such as is used for showing the spectrum with rarefied gas; the other as shown in Fig. 1 of accompanying plate, for the spark spectrum with Leyden jar. A small amount of pure metallic arsenic was introduced into each tube, and they were then repeatedly exhausted, each time replacing with hydrogen. After the final exhaustion, the tubes were heated, in order to fill them with the vapor of arsenic. But, upon passing the spark through them, we could obtain no definite or satisfactory result. The arsenic spectrum was feeble, the hydrogen brilliant, and the fluted indefinite bands which accompany the hydrogen spectrum wholly obscured the phenomenon.

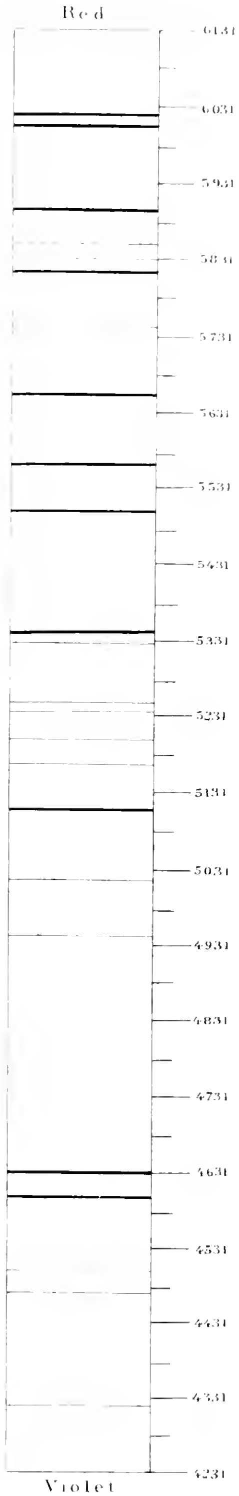
Judging from the statements in Roscoe's spectrum analysis that these fluted portions of the hydrogen spectrum were accidental and due to impurities, we attempted to get rid of them in order to bring out the arsenic spectrum. We, therefore, prepared several tubes with pure hydrogen. We arranged tubes with two outlets, in order to pass a continuous current through the whole apparatus, including the Sprengel pump which was connected with one of the openings. The hydrogen was prepared from pure zinc and sulphuric acid, and most carefully dried. We would allow the gas to slowly pass through the apparatus for twenty-four hours, then exhaust, and after exhaustion heat the tube as hot as practicable under the circumstances, then pass dry hydrogen and repeat the process several times. Notwithstanding these precautions, we found, after a great many trials with different tubes, that the fluted and more or less diffused spectrum always accompanied the four principal hydrogen lines. It being then impossible to eliminate the diffused spectrum, we next tried alloying the platinum electrodes with arsenic, and experimented with these in a rarefied atmosphere of hydrogen, both with continuous discharge of Rumkorff coil, and with interrupted discharge with Leyden jar. We now obtained very definite arsenic bands, apparently the same in both cases; but the effect was very momentary, and gave no opportunity for measurement. The spectrum while it lasted was very striking; but, as soon as the arsenic upon the extreme point of the electrode passed off, the characteristic spectrum disappeared.

We were by this experience led to contrive the following apparatus, by which we obtained the desired result, and the same may be useful in experiments on the spectra of similar volatile substances. A longitudinal section of the tube, one half the original size, is shown in Fig. 2 of plate. The portions AA' and A'' are of rather coarse thermometer tubing. BB' is a tube left open at B, and drawn to a capillary point at B'. The substance to be examined, after being reduced to a powder, is introduced through the opening at B until the tube is about half full. Then one end of a platinum wire is buried in the substance, and the other end is fused into the tube at B, thus closing the opening. After the hydrogen has been allowed to flow through the tube a sufficient length of time, the opening at A is closed by a nipper-tap, and the tube is exhausted at A''. Now upon connecting B with the negative electrode, and C with the positive electrode, of a small induction coil, we have the vapor of the substance in the tube BB' carried in the current through the tube A' where the spectrum may be observed.

One advantage of this particular form of tube is, that, in order to compare the spectrum of our substance with that of hydrogen, we have only to reverse the current, making C the negative pole, and then all the lines except those of hydrogen at once disappear.

The arsenic spectrum thus obtained is very brilliant, and consists of

Fig: 3.



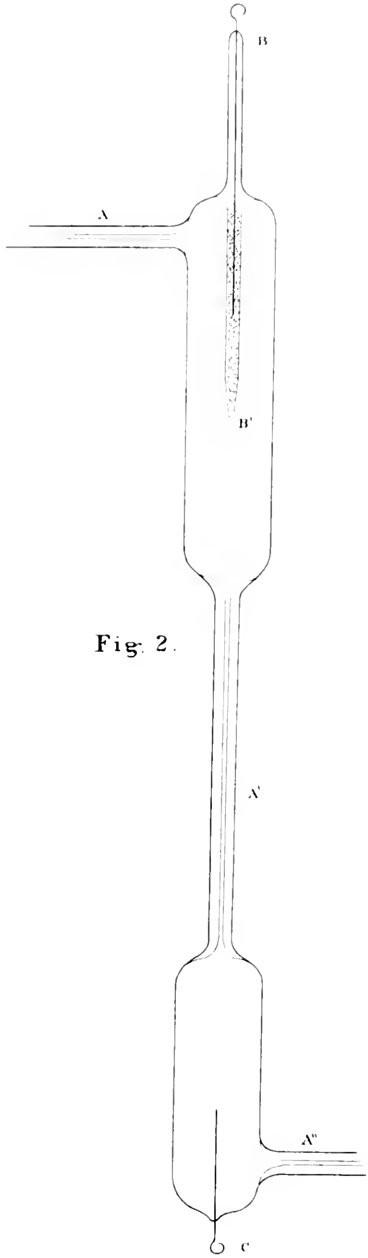


Fig: 2.

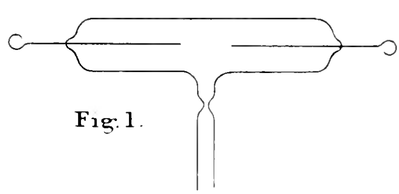


Fig. 1.

numerous well-marked sharply defined bands. The bands are most numerous and brilliant in the green, and these give the prevailing tone to the spectrum. But there is one very striking yellow band, and there are also several bands in the blue and violet. Then in the red there is an interesting double band, the two members of which are the same distance apart as the two *D* lines. In addition, there may be also a more or less diffused spectrum, which in some parts cannot be distinguished from the similar diffused spectrum of hydrogen, and it is worthy of remark in this connection, as indicating the purity of the material used, and also that the diffused fluted spectrum above referred to cannot come from the material of the tube, that no trace of the sodium line was seen. No account was taken of the diffused spectrum, as it only appeared when the battery was unusually strong.

In speaking of the diffused spectrum of arsenic, we do not mean the same kind of diffused spectrum as mentioned above in connection with nitrogen. The diffused arsenic spectrum appears to be composed of innumerable faint lines, wholly independent of the other more brilliant characteristic arsenic bands; and we only use the term "diffused" for convenience, to express that the lines are very faint and too numerous to measure.

The arsenic employed had been carefully purified by sublimation, and preserved under distilled water. We used for measuring the wave-lengths of the spectrum lines the spectroscope described by Professor J. P. Cooke [Am. Jour. of Science, Vol. XL., Nov., 1865]. In this instrument, the train of prisms can be adjusted accurately to the angle of minimum deviation, which was observed in each case. We used five flint prisms of 45° angle each, and to reduce the angular measurements to wave-lengths, we employed the method described by W. M. Watt in his "Index of Spectra."

We, in the first place, measured with care the angles of minimum deviation of the most prominent Frauenhoffer lines, and verified and somewhat multiplied the data by measuring also the angles for characteristic lines of the hydrogen, lithium, sodium, thalium, and strontium spectra. These we combined with the wave-lengths of the same lines given by Angström, by ordinates and abscissas in the usual way, and the curve drawn through the points so determined was so regular and of such small curvature, that it was easy to interpolate with minutes of arc to five *tenth-metres* of wave-length, as usually expressed.

The instrument is capable of reading to five seconds of arc, and with the full bank of ten prisms it would give the wave lengths to tenth-metres with perfect accuracy. With the comparatively feeble light of the arsenic spectrum, as we first observed it, we did not think it advisable to use the full power of the instrument. We therefore used five prisms, as stated, and read to one minute of arc. We always began each series of observations by setting the cross-wire of the micrometer on the sodium line, after the telescope had been adjusted to the angle of minimum deviation of this line as first observed. There was seldom any observed difference in this angle. But when by change of temperature, or otherwise, an alteration of two or three minutes had taken place, we found, on readjusting the cross-wire, that the relative position of the spectrum lines was, to the limit of accuracy of our measurement, wholly unchanged.

We give below the table of wave-lengths of the principal lines of the arsenic spectrum.

6023	tenth-metres.	5230	tenth-metres.
6013	"	5195	"
5853	"	5163	"
5833	"	**5103**	"
5813	"	5013	"
5743	"	4941	"
5653	"	**4623**	"
5563	"	**4593**	"
5498	"	4493	"
[**5340**]	"	4463	"
5323	"	4313	"
5245	"		

The wave-lengths printed in heavy type denote the bands which are most brilliant and give character to the spectrum. The other lines are less constant and less distinct, and in some instances may be due to accidental causes.

We were surprised to find among the bright lines, that the one which in the table is enclosed in brackets corresponds to the green thalium band, and upon examining the spectrum it appeared evident that thalium must be present in the arsenic in large quantities, as the thalium band was fully as bright as any of the arsenic bands.

The accompanying diagram (Fig. 3 of plate) will give some idea of the general appearance of the arsenic spectrum.

INVESTIGATIONS ON LIGHT AND HEAT, PUBLISHED WITH AN APPROPRIATION FROM THE RUMFORD FUND.

III.

THERMO-ELECTRICITY. — PELTIER AND THOMSON EFFECTS.

BY CHARLES BINGHAM PENROSE.

Presented by Professor Trowbridge, June 8, 1881.

THERE are two theories regarding the cause of the thermo-electric current. That held by Le Roux, Clausius, and most French physicists is that the heat effects which cause the current take place only at the junctions. The theory held by Sir William Thomson, Tait, and Maxwell is that the heat effects which cause the current take place, not only at the junctions, but along the metals themselves.

Let π and π^1 denote the heat — measured in dynamical equivalents — absorbed and evolved at the hot and cold junctions respectively in unit time by unit current. Let E be the electromotive force of a battery, maintaining a current I in such a direction as to cause absorption of heat at the hot junction. Then if R be the whole resistance of the circuit, we have by Joule's law and the first law of thermodynamics: —

$$EI + \pi I - \pi_1 I = RI^2. \qquad (1)$$

Supposing the whole energy of the current wasted in heat. Also: —

$$I = \frac{E + \pi - \pi'}{R} \qquad (2)$$

It appears, then, that, owing to the excess of the absorption of heat at the hot junction over the evolution at the cold junction, there arises an electromotive force $\pi - \pi_1$ helping to drive the current in the direction giving heat absorption at the hot junction. We may suppose, and shall henceforth suppose, that $E = O$, and then the current will be maintained entirely by the electromotive force $\pi - \pi_1$.

Now, apply the second law of thermodynamics. "The application of the second law is of a more hypothetical character. Still it seems a reasonable hypothesis to assume that the Peltier effects, and other heat effects, if any, which vary as the first power of the current strength, taken by themselves, are subject to the second law of thermodynamics."

This law gives: —

$$\frac{\pi I}{\theta} - \frac{\pi' I}{\theta'} = 0$$

θ and θ^1 being the absolute temperatures of the hot and cold junctions.

$$\therefore \frac{\pi}{\theta} = \frac{\pi'}{\theta'} \quad . \quad (3)$$

$$\therefore \pi = C\theta$$

C being a constant, depending only on the nature of the metals.

In accordance with this, the electromotive force in the circuit $= C(\theta - \theta_1)$ $\therefore$ it would be proportional to the difference between the temperatures of the junctions.

"Now, this conclusion is wholly inconsistent with the existence of thermo-electric inversion. We must, therefore, either deny the applicability of the second law, or else seek for reversible heat effects other than those of Peltier." This was essentially the reasoning that led Thomson to the discovery of the Thomson effect. Before questioning Thomson's conclusion, it is best to consider the formulæ which are deduced from his hypothesis.

Suppose we have a circuit of two metals. Let the heat absorbed by the Thomson effect in passing from a point at temperature θ to a point at temperature $\theta + d\theta$ in one metal be $\sigma_1 d\theta$ per unit current per unit time. Let $\sigma_2 d\theta$ be the corresponding expression for the other metal. σ_1 and σ_2 are functions of the temperature. They depend on the nature of the metals, but are independent of the form or magnitude of the section of the conductors. These effects are proportional to the first power of the current strength.

By the first law of thermodynamics: —

$$EI + \pi I - \pi' I + I\int_{\theta'}^{\theta}(\sigma_1 - \sigma_2)\, d\theta = RI^2 \qquad (\alpha)$$

$$\therefore I = \frac{E + \pi - \pi' + \int_{\theta'}^{\theta}(\sigma_1 - \sigma_2)\, d\theta}{R} \qquad (\beta)$$

If $E = O$ we have as the electromotive force of the thermo-electric current, by the same reasoning as before: —

$$e = \pi - \pi' + \int_{\theta'}^{\theta}(\sigma_1 - \sigma_2)\, d\theta \qquad (\gamma)$$

The second law of thermodynamics gives: —

$$o = \frac{\pi}{\theta} - \frac{\pi'}{\theta'} + \int_{\theta'}^{\theta} \left(\frac{\sigma_1 - \sigma_2}{\theta} \right) d\theta \qquad (\delta)$$

Differentiate (δ)

$$\frac{d}{d\theta} \left(\frac{\pi}{\theta} \right) + \frac{\sigma_1 - \sigma_2}{\theta} = 0 \qquad (\eta)$$

$$\therefore \frac{\sigma_1 - \sigma_2}{\theta} = - \frac{d}{d\theta} \left(\frac{\pi}{\theta} \right)$$

performing the differentiation

$$= \frac{\theta \frac{d\pi}{d\theta} - \pi}{\theta^2}$$

$$\therefore \sigma_1 - \sigma_2 = - \frac{d\pi}{d\theta} + \frac{\pi}{\theta}$$

Substitute in (γ)

$$e = \pi - \pi' - \int_{\theta'}^{\theta} \left(\frac{d\pi}{d\theta} - \frac{\pi}{\theta} \right) d\theta$$

$$= \pi - \pi' - (\pi - \pi') + \int_{\theta'}^{\theta} \frac{\pi}{\theta} d\theta$$

$$\therefore e = \int_{\theta'}^{\theta} \frac{\pi}{\theta} d\theta \qquad (\xi)$$

or

$$e = - \int\int \frac{\sigma_1 - \sigma_2}{\theta} \qquad (\omega)$$

from (η).

If, as Tait supposes, σ is proportional to the first power of the absolute temperature, $\sigma = k\theta$ equation (w) becomes: —

$$e = - [k\theta^2 + k'\theta + k'']$$

$\therefore$ the thermo-electric curve is a parabola.

The basis of all the preceding is taken from the British Encyclopædia. Maxwell's demonstration is essentially the same. (§§ 249–251, Vol. I., Maxwell's Electricity and Magnetism.)

When no current was passing from an external battery eq. (2) became

$$I = \frac{\pi - \pi'}{R}$$

Let

$$\pi - \pi' = \mathfrak{S} \qquad \therefore I = \frac{\mathfrak{S}}{R}$$

In other words, it was said that the heat ϑ — the amount of heat absorbed in unit time by unit current in crossing the hot junction exceeding that evolved at the cold junction — was sufficient to produce a current of strength I.

Now, when a current from an outside source is passed through the circuit in the same direction as I, an amount of heat $\vartheta\ C$ disappears, — C being the strength of the external current: what becomes of this heat? A certain amount of energy disappears: what is its equivalent?

If the heat ϑ is sufficient to produce a current of strength I, the heat $\vartheta\ C$ is great enough to produce a current C times as strong as I $\therefore$ a current of strength CI.

When the current C is passing through the circuit we should then expect to find it increased (or decreased) by a current CI — the equivalent of the amount of heat absorbed by C. Thus, when an external current passes through a thermo-electric element, we should expect to have as the total current in the circuit, $C + I \pm CI$; that is, the resultant current should be much greater (or much less) than $C + I$.

But, in several experiments that were made, it was observed that the resultant current always equalled exactly $C + I$.

Now, if the Peltier effect is the cause of the thermo-electric current, enough heat has disappeared to create a current C times as strong as the proper thermo-electric current; but experiment shows that the thermo-electric current is perceptible, while this other current is imperceptible. We must, therefore, conclude that this current, which is equivalent to an amount of heat $\vartheta\ C$, is not C times as great as the proper thermo-electric current; and hence the proper thermo-electric current cannot be the equivalent of the amount of heat ϑ. In other words, the Peltier effect cannot be the cause of the thermo-electric current.

An unsuccessful experiment was made to prove that the Peltier effect was not great enough to be the cause of the thermo-electric current. The failure was due to the fact that the heat absorbed was too small to be measured. The principle of the experiment was as follows: —

Place the thermo-electric junction in a vessel of mercury, after heating the mercury to a certain temperature let it cool, the circuit being broken so that no current passes. From a thermometer placed in the mercury read the temperatures at definite times, and construct a curve, having the temperatures as ordinates, and the corresponding times as abscissas. Next draw a similar curve when the thermo current is passing. Let the current run through a galvanometer, and observe the deflection of the galvanometer every time a reading of the thermometer is taken. This will give a third curve, giving the thermo-electric current at any time, corresponding to any temperature of the second curve. Finally, pass a current of known strength I from an external source through the junction in the direction of the proper thermo current, and get a fourth curve representing the fall of temperature for this case.

The equations of all these curves being known, we can find from the two first the rate at which heat is absorbed by a thermo-electric current of any strength given by the third curve. Let $h =$ the heat absorbed in unit time by this thermo-electric current of strength i. From the first and fourth curves we can find the amount of heat H absorbed in unit time by the battery current I.

Now, if the heat H is merely the heat absorbed by the Peltier effect, we have — as the heat of the Peltier effect is simply proportional to the current strength: —

$$h : H :: i : I. \qquad (4)$$

But if, as I supposed, h was much greater than the heat absorbed by the Peltier effect, this equation would not be satisfied.

The thermo element used was of German silver and iron. The hot junction was shaped in the form of a ring and placed in a small vessel of mercury, the bulb of the thermometer being placed in the centre of the ring. The first two curves, however, were identical, though German silver and iron constitute one of the strongest thermo elements. The thermometer fell at exactly the same rate whether the current was passing or not.

We have not, however, considered the Thomson effect. But the same reasoning used in the case of the Peltier effect applies also here.

From equation (γ) it was seen that the proper thermo-electric current was proportional to

$$\pi - \pi' + \int_{\theta'}^{\theta} (\sigma_1 - \sigma_2)\, d\theta$$

Let

$$\int_{\theta'}^{\theta} (\sigma_1 - \sigma_2)\, d\theta = S$$

Then this current is proportional to $\mathfrak{9} + S$. That is, $\mathfrak{9} + S$ is the whole heat absorbed in the circuit by unit current in unit time.

If, now, we pass through the circuit an external current of strength C, the whole heat absorbed is $(\wp + S)$ C.

This should be enough heat to produce a current C times as strong as the proper thermo-electric current, *if the thermo-electric current is due to the heat* $\wp + S$.

If, then, I be the strength of the thermo-electric current, we should expect that the whole current in the circuit would be:—

$$C + I \pm CI.$$

But experiment shows that the whole current exactly $= C + I$. We must, then, conclude that the current which is equivalent to the heat $(\wp + S)$ C is not C times as great as the proper thermo-electric current; consequently, the thermo-electric current cannot be the equivalent of the heat $\wp + S$. In other words, the thermo-electric current cannot be the equivalent of the Thomson and Peltier effects.

All the experiments that have been made on the Peltier and Thomson effects have been made when these phenomena appeared as the result of a current, not when they appeared as its cause. The heat absorbed by a thermo-electric current itself has never been measured. All measurements of the heat effects have been made by passing an outside current through the circuit, the heat effects due to the thermo-electric current itself being too small to be measured. But we have no right to suppose, *à priori*, that at the hot junction of a thermo element the only heat absorbed in the production of the thermo-electric current is that due to the Peltier effect. If, in the experiment that I attempted, h had satisfied equation (4), then the heat due to the Peltier effect would have been the only heat absorbed at the hot junction by the thermo-electric current. But, as the experiment was a failure, there are no grounds for this assumption. It is, therefore, not surprising that equations (1), (2), and (3), which are based on the assumption that the Peltier effect is the only heat effect at the hot junction which causes the thermo-electric current, should give results inconsistent with experiment.

The Thomson effect, even more than the Peltier effect, appears to be the result of a current, not the cause.

All experiments on the Thomson effect are made by passing a strong current along a bar of metal, the ends of which are at different temperatures. It is then found that the temperatures of fixed points on the bar are different when the current is passing from what they were before it passed. In some metals the temperature is raised, in others diminished, as the current passes from the hot to the cold end of the bar. Thomson attributed this to the fact that in some metals the current evolved heat in passing from hot to cold parts; in others it absorbed heat. And the difference between the heat absorbed in one metal, and that evolved in the other, he supposed to be one cause of the thermo-electric current.

Another explanation is that the current of electricity changes the thermal conductivity of the bar, in some metals increasing the conductivity, and diminishing it in others.

It is well known that the electric current modifies the physical properties of metals along which it passes. It changes their cohesion, in some cases increasing it, in others diminishing it. The elasticity of metals is also changed under the influence of electricity. What is more probable than that the thermal conductivity should also be changed?

There are many objections to the view taken by Thomson. The numbers expressing the Thomson effect bear no apparent relation to the thermo-electric current; and, moreover, the effect is entirely too small to produce even the weakest thermo-electric current.

The fact that the formulæ deduced on Thomson's hypothesis agree with experimental results is of but little importance. The thermo-electric curves determined experimentally are, approximately, parabolas. Thomson's equation is also that of a parabola. But any theory, based on the supposition that the heat effects are proportional to the current strength, will give the equation of a parabola.

It was mentioned that the current $(\mathfrak{S} + S)\ C$ was imperceptible. In the few experiments that were made the current C was very feeble, not much greater than the thermo-electric current I, which was given by an element of German silver and iron. The resistance of the circuit was about two hundred ohms. Consequently, the current equivalent to the extremely small amount of heat $(\mathfrak{S} + S)\ C$ might readily have produced no apparent effect.

I have attempted to show that the Peltier and Thomson effects cannot be the whole cause of the thermo-electric current. The true cause is yet to be discovered.

Many unsuccessful attempts have been made to find relations between the strength of the thermo-electric current and the physical properties of the metals of the thermo element. To completely solve the problem, however, we must know the way in which the physical properties of the metals change, when the metals are under the influence of heat and a current of electricity.

The thermo-electric current depends essentially on the differences of the two metals. The slightest change in the structure or the composition of the metals makes a perceptible change in the current. Therefore, to determine the variations of the electric current with the temperature, it is necessary to know the variations of the metals with the temperature. A junction of iron and silver might be expected to give twice as strong a current at 100° as at 50°. This might be the case if the iron and silver were exactly the same at 100° as at 50°; but iron at 100° is a different metal from iron at 50°: the thermal conductivity, the electric conductivity, the specific gravity, and many other properties have changed. It may be due to this fact — that the properties of the metals change with the temperature — that the thermo-electric lines are not straight.

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IV.

CONTRIBUTIONS FROM THE PHYSICAL LABORATORY OF HARVARD UNIVERSITY.

THERMOELECTRIC LINE OF COPPER AND NICKEL BELOW 0°.

CHARLES BINGHAM PENROSE.

Presented by Professor Trowbridge, June 8, 1881.

THE great difficulty to be encountered in experiments on thermo-electricity is the variation in the results obtained by different experimenters. There can be no comparison with previous experiments when all the results are different. As an example, take the electromotive force of a junction of bismuth and copper — with one junction at 0° and the other at 100° — as obtained by different experimenters: —

Wheatstone	0.00106
Neumann	0.00390
J. Regnault	0.00286
E. Becquerel	0.00483

These results are referred to the electromotive force of a Daniell element as unity.

It will be observed that the last result is over four times as great as the first.

There are many causes which might produce this variation. Slight differences in the structure of the metals often affect the results, and the results obtained with the same metal, before and after it has been subjected to pressure and tension, are often very different. A piece of hard steel always gives different effects from a piece of soft steel. But these causes must all be of minor importance; the great trouble consists in the impurity of the metals. It is well known that other electrical properties of metals are greatly changed by slight differences in purity. Thus the specific resistance of copper may be increased fifty per cent by the presence of slight impurities.

It is, therefore, of the greatest importance to use absolutely pure substances in all experiments on thermoelectricity. In the following experiments, therefore, the metals used have always been chemically pure, — deposited by electrolysis.

The first experiments were made with copper and nickel. The nickel was about twelve inches long and V-shaped. To each end was soldered a strip of copper, about eight inches long. During the experiment one end was placed in melting snow and the other in a mixture of snow and calcic chloride, — 30 grammes of snow to 40 of calcic chloride. The two junctions, and also the metals as far as they were in contact with the freezing mixture, were coated with shellac. A mercury thermometer — the zero point of which had previously been verified — was bound to the colder junction of the copper and nickel. Copper wires, soldered to the free ends of the two strips of electrolytic copper, connected the thermoelectric element with the galvanometer, the circuit being made or broken by means of a key. The galvanometer was a Thomson's mirror galvanometer of low resistance. The mixture of snow and $CaCl_2$ generally gave a temperature of about — 25° C. From this the temperature gradually rose, and at every 5° increase the circuit was made, and the deflection of the galvanometer observed. When the temperature had reached 0° the junction was placed in a vessel of water and heated gradually to about 80°C, the deflection of the galvanometer being observed for every ten degrees increase of temperature. The following are the results from five series of experiments. The junctions were reversed in every alternate series; that is, the junction that, in the first, was placed in melting snow, was, in the second, placed in $CaCl_2$ and snow. This obviated whatever irregularities might arise from any difference between the two junctions.

The first column gives the temperature of the colder junction. The second the number of the experiment. The third the resistance of the whole circuit and the galvanometer. The resistance of the latter was six ohms. The fourth gives the deflection of the galvanometer needle. The fifth gives the product of this deflection into the resistance, which is directly proportional to the electromotive force.

t	Number of Experiment.	Resistance. R	Deflection. d	$d \times R$
—25°	2	36	14.5	522.0
"	4	36	15.0	540.0

Mean value of $d \times R = 531.0$.

Temperature. t	Number of Experiment.	Resistance. R	Deflection. d	$d \times R$	Mean value of $d \times R$.
—20°	1	56	8.4	470.4	
"	2	36	11.5	414.0	
"	5	36	12.6	453.6	446.0
—15°	1	56	6.1	341.6	
"	2	36	8.3	298.8	
"	3	36	7.7	277.2	
"	4	36	9.8	352.8	
"	5	36	8.8	316.8	315.4
—10°	1	56	4 2	235.2	
"	2	36	4.8	172.8	
"	3	36	5.2	187.2	
"	4	36	6.0	216.0	
"	5	36	6.5	234.0	209.0
—5°	1	56	2.1	117.6	
"	3	36	2.6	83.6	
"	4	36	2.5	80.0	
"	5	36	4.3	154.8	109.0
+10°	1	56	4.5	252.0	
"	2	36	7.5	270.0	
"	3	36	6 6	237.6	
"	4	36	6.8	244.8	
"	5	36	6.3	226.8	246.2
+20°	1	56	9.1	509.6	
"	2	36	13.5	486.0	
"	3	36	13.5	486.0	
"	4	36	14.0	504.0	
"	5	36	14.0	504.0	497.9
+30°	1	56	14.0	784.0	
"	2	86	8.6	739.6	
"	3	36	21.4	770.4	
"	4	56	14.0	784.0	
"	5	56	13.6	761.6	767.9
+40°	1	56	18.5	1036.0	
"	2	86	11.7	1006.2	
"	3	106	9.6	1020.3	
"	4	106	9.7	1028.2	
"	5	56	18.5	1036.0	1025.3
+50°	1	56	23.5	1316.0	
"	2	106	12.3	1303.8	
"	3	206	6.3	1297.8	
"	4	206	6.3	1297.8	
"	5	206	6.3	1297.8	1302.6
+60°	1	56	28.0	1568.0	
"	2	206	7.7	1686.2	
"	3	206	7.6	1565.6	
"	4	206	7.6	1565.6	1596.3

The preceding values of $d \times R$ are directly proportional to the values of the electromotive forces. The formula for the electromotive force is $E = kRd$, in which k is the constant of the galvanometer, R is the resistance of the circuit, and d is the tangent of the deflection of the galvanometer needle.

The constant of the galvanometer was determined by means of a small gas battery. The electromotive force of the gas battery was found, by means of Thomson's electrometer, to be .285 of a Daniell element. The electromotive force of a Daniell element $= 1.079$ volts, hence that of the gas battery $= 1.079 \times .285 = .307515$ volts $= 30751500$ absolute units, since one volt $= 10^8$ absolute units, in the C. S. G. system. The formula for the constant is

$$k = \frac{E'}{R'd'}$$

where $E' =$ the electromotive force of the battery, R' the whole resistance of the circuit, and d the tangent of the deflection of the galvanometer needle,

$$\therefore k = \frac{E'}{R'd'}$$

Consequently the preceding formula for the electromotive force $E = k\ R \tan a$ becomes

$$E = \frac{E'}{R'd'}\ d \times R.$$

The constant by which the preceding results in the tables are to be multiplied in order to reduce the electromotive force to absolute units is then $\frac{E'}{R'd'} = k$.

It was found that when $R' = 12000$ $d' = 45.0$.
" " " $R' = 11000$ $d' = 50.5$.

The first gives for $k = 56.9$; the second 55.3; mean value of $k = 56.1$.

Hence to obtain the absolute values of the electromotive forces the values of $d \times R$ given by the tables must be multiplied by 56.1.

After the preceding experiments a still lower temperature was obtained by means of solid carbonic dioxide and ether. Two experiments were made, the temperatures in the first being measured by an ether thermometer, in the second by an air thermometer. In both the same metals, copper and nickel, employed in the previous experiment, were used.

In the first experiment the cold mixture was placed under the receiver of an air pump. The exhaustion was maintained by means of a Richard's air pump. This occasioned a faster evaporation of the ether, and a consequent greater decrease of temperature, than could otherwise have been maintained.

The results obtained are as follows: —

Temperature given by Ether Thermometer.	Resistance. R	Deflection. d	$d \times R$
—40°	96	16.2	1555.2
—52.5°	96	20.0	1920.0
—52.5°	96	19.5	1872.0
—52.0°	96	18.7	1715.2

In the second experiment the temperatures were measured by means of the air thermometer. The bulb of the air thermometer, the junction of copper and nickel, and the bulb of the ether thermometer, were placed side by side and surrounded with solid carbonic dioxide, over which ether was poured. The simultaneous readings of the galvanometer, of the air thermometer, and of the ether thermometer were then taken, after the air thermometer had reached its lowest temperature.

The following are the results: —

Temperature given by Air Thermometer.	Temperature given by Ether Thermometer.	Resistance. R	Deflection. d	$d \times R$	Mean value of $d \times R$
60.2 C	42.3° C	106	13.5	1431.0	
"	"	206	6.8	1400.8	
"	"	156	9.0	1404.0	1411.9

In the preceding two experiments the constant of the galvanometer was obtained, as before, by means of the gas battery.

In the first experiment, $R = 14000$ $d = 47$

$$\therefore k = \frac{30751500}{14000 \times 47} = 46.7$$

In the second experiment, $R = 12000$ $d = 48$

$$\therefore k = \frac{30751500}{12000 \times 48} = 53.3$$

Consequently to obtain the values of the electromotive force for the preceding experiments the values of $d \times R$ must in the first experiment be multiplied by 46.7, in the second by 53.3.

From the preceding table it is seen that the ether thermometer cannot be used to measure temperatures accurately. The coefficient of expansion of ether is by no means constant, and besides the ether adheres to the sides of the thermometer tube. The real value of the coefficient cannot be obtained from these results, as only the bulb of the thermometer was subjected to the low temperature; but as the bulb was very large in proportion to the bore of the tube, an approximate value may be obtained.

When the temperature, as given by the air thermometer, was — 60° .2 C the ether thermometer stood at — 42° .3 C; the reading of the ether thermometer was $\frac{42.3}{60.2}$ of what it should have been if it contracted regularly. Thus temperatures in the neighborhood of — 42° C, as given by the ether thermometer, can be corrected, and more approximate results obtained, by multiplying by $\frac{60.2}{42.3} = 1.42$.

It should be remembered that the temperatures thus obtained are by no means accurate; they are only rough approximations.

Applying this correction to the temperatures given by the ether thermometer, we have: —

Temperatures given by Ether Thermometer reduced by multiplying by 1.42.	Resistance. R	Deflection. d	$d \times R$
—56 8° C	96	16.2	1555.2
—74.5° "	96	20.0	1920.0
—74.5° "	96	19.5	1872.0
—73.8° "	96	18.7	1715.2

If now the values of $d \times R$ from all the preceding tables are multiplied by the constants necessary to obtain the absolute values of the electromotive forces, the preceding results may be summed up in the following table. The first column gives the temperatures of one junction of the copper and nickel; the other junction was always at 0°. The second column gives the absolute values of the corresponding electromotive forces, in the C. G. S. system of units. The third column gives the differences between the alternate electromotive forces. And the fourth the differences between the corresponding temperatures.

Temperature.	Absolute value of the Electromotive force.	Differences between alternate Electromotive Forces.	Difference between alternate Temperatures.
+60° C	89552.43	....	...
+50° "	73075.86	16476.57	10°
+40° "	57519.33	15556.53	10°
+30° "	43079.19	14440.14	10°
+20° "	27932.19	15147.00	10°
+10° "	13811.8	14120.39	10°
— 5° "	6114.9	....	...
—10° "	11724.9	5610.0	5°
—15° "	17693.9	5969.0	5°
—20° "	25020.6	7326.7	5°
—25° "	29789.1	4768.5	5°
—56.8° "	72627.84	42838.74	31.8
—60 2° "	75254.27	2626.43	3.4
—73.8° "	80099 84	4844.57	13 6
—74 5° "	88496.5	8396.66	0.7

NOTE. — Between 74.5° and 25° the temperature rose too rapidly to obtain intermediate readings with the air thermometer.

If these results are represented by a curve, of which the abscissas are proportional to the temperatures, and the ordinates to the corresponding electromotive forces, it is seen that the curve is approximately a right line for all the points except those corresponding to the temperatures obtained by the ether thermometer. It was to be expected that these points would not lie exactly on the curve, as the temperatures were so roughly obtained.

The thermoelectric line for temperatures below 0° is almost a direct continuation of the line above 0°; the two, however, are inclined at a slight angle. The reason of this is probably due to the fact that for temperatures above 0° the piece of electrolytic copper soldered to the hot end of the nickel became more heated throughout than the piece soldered to the cold junction; and consequently the points of contact where the copper galvanometer wires joined the two pieces of electrolytic copper were unequally heated, and a subsidiary current was produced. It was found that when both junctions of copper and nickel were kept at the same constant temperature, a very small current was produced when one piece of the electrolytic copper was slightly heated above the other.

From these experiments it appears that an ether thermometer cannot be used to measure low temperatures accurately, not only because the ether adheres to the sides of the tube, but because its coefficient of expansion is variable; also that the thermoelectric line of copper and nickel, when chemically pure, is practically straight, at least between + 60° C and — 60° C.

A thermoelectric element of pure copper and nickel can therefore be used as an accurate means of measuring low temperatures.

Examination of Ether Thermometer.

After the preceding experiments the ether thermometer was more critically examined. The bulb was placed in a mixture of calcic chloride and snow, beside the bulb of a mercury thermometer; and afterwards in water, which was heated to about + 30° C.

The results are contained in the following table. The first column gives the temperatures shown by the mercury thermometer; the second column the corresponding temperatures shown by the ether thermometer.

Temperatures given by Mercury Thermometer.	Temperatures given by Ether Thermometer.	Temperatures given by Mercury Thermometer.	Temperatures given by Ether Thermometer.
+30° C	+28.0° C	—15° C	— 9.8° C
+25° "	+23.6° "	—20° "	—14.0° "
+20° "	+19.0° "	—23° "	—16.1° "
+15° "	+14.7° "	—24° "	—16.7° "
+10° "	+10.3° "	—25° "	—17.4° "
+ 5° "	+ 6.2° "	—26° "	—18.1° "
— 5° "	— 1.6° "	—60.2° "	—42.3° "
—10° "	— 5.6° "		

The zero point of the ether thermometer was determined by burying the bulb in melting snow for twenty minutes. It was then found that the true zero was 2° above the zero of the scale. Applying this correction to the preceding results, it is still seen that the ether expanded and contracted very irregularly.

It is true that only the bulb of the thermometer was subjected to the different temperatures; but the bulb was very large in proportion to the base of the tube, and as an ether thermometer must necessarily be made rather long, it is, in the great majority of cases, impossible to subject any more than the bulb to the temperature to be determined.

V.

CONTRIBUTIONS FROM THE CHEMICAL LABORATORY OF HARVARD COLLEGE.

By W. H. Melville.

Presented, July, 1881.

CRYSTALLINE FORM OF CRYOLITE.

The crystalline form of Cryolite was described by Dana in his "System of Mineralogy," 1868, as Trimetric, but, as he distinctly stated, the system in which the mineral crystallizes was considered doubtful. Des Cloizeaux has since investigated the optical characters, and determined the system of crystallization to be Triclinic, which Websky corroborates by his measurements.

The difficulties which are presented in the determination by measurements are two-fold. In the first place, the angles which the three most prominent faces make with each other are very closely right angles, thus suggesting one of the three orthometric systems; and, secondly, these angles are rendered uncertain by the presence of striations, a habit almost invariable. Minute crystals (Figs. 1 and 2), varying from three to five hundredths of an inch in length, were employed in the following determination, and these were taken from the surface of a pure white specimen of Cryolite. By mounting a large number of crystals, it was observed that the angles made by the three pinacoid planes with each other were quite constant, — the greatest difference from the means amounting to about 3′, — so that all suspicion which I entertained as to the probability of their being right angles, was removed. A few colorless transparent crystals, absolutely free from striæ, and showing no evidence of twinning, were found, and from these the fundamental angles used in calculating the elements of the crystalline form were taken. They are represented in Fig. 1. The plane (001) was chosen for the basal section, because it formed the termination of the crystals, and was not commonly striated.

Crystalline Form—Triclinic.

Forms $\{100\}$, $\{010\}$, $\{001\}$, $\{1\bar{1}0\}$, $\{201\}$
$\{111\}$, $\{1\bar{1}1\}$, $\{\bar{1}\bar{1}1\}$, $\{\bar{1}11\}$, and $\{311\}$

Fundamental Angles.

Between normals	(100)	and	(010)	— 91° 53′ 30″
	(100)	„	(001)	— 89° 47′ 50″
	(010)	„	(001)	— 89° 55′ 30″
	(111)	„	(001)	— 54° 10′
	(111)	„	(010)	— 55° 42′ 30″

From these were calculated:—

Brachydiagonal $a = 1$
Macrodiagonal $b = 1.00362$
Vertical axis $c = 1.00185$

Angles between axes	X Y =	88° 6′ 30″
	X Z =	90° 12′ 20″
	Y Z =	90° 4′ 33″

Angles between normals.	Measured.	Calculated.	Websky.
(100) and (010)	— 91° 53′ 30″	. . .	91° 57′
(100) " (001)	— 89° 47′ 50″	. . .	89° 36′
(010) " (001)	— 89° 55′ 30″	. . .	89° 58′
(111) " (001)	— 54° 10′	. . .	
(111) " (100)	— 55° 42′ 30″	. . .	
(111) " (100)	— 55° 31′	55° 27′ 57″	
$(1\bar{1}1)$ " (001)	— 55° 40′ 13″	55° 36′ 13″	
$(1\bar{1}1)$ " (100)	. . .	53° 16′	
(001) " $(1\bar{1}0)$	— 89° 52′	89° 54′ 20″	
(001) " (201)	— 63° 20′ 59″	63° 19′ 43″	
(201) " (100)	— 26° 24′ 22″	26° 28′ 7″	
(111) " (311)	— 29° 57′ 50″	30° 7′ 30″	
(311) " (100)	— 25° 24′ 30″	25° 25′ 31″	
(311) " (001)	— 72° 2′ 30″	72° 5′ 17″	
(100) " $(1\bar{1}0)$	— 44° 1′ 54″	43° 57′ 18″	
$(1\bar{1}0)$ " $(0\bar{1}0)$	— 44° 4′ 38″	44° 9′ 12″	
(001) " $(\bar{1}\bar{1}1)$	— 54° 18′ 35″	54° 25′ 43″	

Fig. 2 shows the distribution of planes upon a second set of crystals which were taken from the same specimen of Cryolite as those represented in Fig. 1. These I consider twins, for the following reasons: — Faces of the form $\{001\}$ were striated parallel to the combination edge $(111) \wedge (\bar{1}\bar{1}1)$, although but very faintly. The striation was shown best by a spectrum which appeared when a crystal was adjusted for measuring the angle between the poles (001) and (111), and this spectrum did not appear when the crystal occupied any other position. Furthermore, if we assume for the moment that the drawing, Fig. 2, is that of a simple crystal, the angle between the poles of $(0\bar{1}0)$ and (001) will be $90° \, 4' \, 30''$, or the supplement of that between (010) and (001). In fact, however, the following are the actual measurements: —

$(100) \wedge (001) = 89° \, 44' \, 30''$	}	$(100) \wedge (\bar{1}00)$
$(001) \wedge (\bar{1}00) = 90° \, 3'$		$179° \, 47' \, 30''$
$(010) \wedge (001) = 89° \, 51' \, 30''$	}	$(010) \wedge (0\bar{1}0)$
$(001) \wedge (0\bar{1}0) = 89° \, 46'$		$179° \, 37' \, 30''$

If, then, we consider the twinning-plane parallel to the form $\{110\}$ (not present on the crystals), by turning one half of the crystal through $180°$, the angle $(0\bar{1}0) \wedge (001) = 89° \, 46'$ will correspond to $(100) \wedge (001) = 89° \, 44' \, 30''$. Again, the angle $(\bar{1}\bar{3}1) \wedge (\bar{1}\bar{1}1)$ is the same as that found for $(311) \wedge (111)$. In other words, the plane, which appears in Fig. 2 as $(\bar{1}\bar{3}1)$, is the other member of the form $\{311\}$, and lies opposite (311).

The form $(2\breve{2})$ of Dana corresponds to what I call $\{311\}$. In no instance were four similar planes of the form $\{311\}$ to be seen on any termination.

In our projection of the poles of the faces, Fig. 3, the great circles [001, 100] and [010, 100] sensibly coincide with the diameters of the circle of the primitive.

The drawing, Fig. 2, was made on the assumption that such crystals were simple, and not twinned, as I have above described them.

WHITE TOURMALINE.

Specimens of White Tourmaline, from Dekalb, St. Lawrence Co., N. Y., have been recently put on exhibition in the Mineral Cabinet of Harvard College, and, being interested to know what planes were represented on the crystals, I undertook the study of them. The rhombohedral forms which were observed on the several crystals are shown in Fig. 4, and also the table.

	Miller.	Bravais-Miller.	Naumann.
Rhombohedrons	$\{211\}$	$\{10\bar{1}4\}$	$+\frac{1}{4}R$
	$\{110\}$	$\{1\bar{1}02\}$	$-\frac{1}{2}R$
	$\{100\}$	$\{10\bar{1}1\}$	$+R$
	$\{11\bar{1}\}$	$\{2\bar{2}01\}$	$-2R$
Scalenohedrons	$\{310\}$	$\{3\bar{1}\bar{2}4\}$	$\frac{1}{4}R3$
	$\{21\bar{1}\}$	$\{3\bar{2}\bar{1}2\}$	$\frac{1}{2}R3$
	$\{31\bar{2}\}$	$\{5\bar{3}\bar{2}2\}$	$\frac{1}{2}R5$
Prisms	$\{2\bar{1}\bar{1}\}$	$\{10\bar{1}0\}$	∞P
	$\{10\bar{1}\}$	$\{2\bar{1}\bar{1}0\}$	$\infty P2$
	$\{21\bar{3}\}$	$\{5\bar{4}\bar{1}0\}$	$\frac{\infty P 5}{2}$

In all crystals the three prisms above tabulated were present, but the alternate planes of $\{2\bar{1}\bar{1}\}$ — or the planes of $k\{2\bar{1}\bar{1}\}$, if we regard the form $\{2\bar{1}\bar{1}\}$ composed of $k\{2\bar{1}\bar{1}\}$ and $k\{11\bar{2}\}$ — were far less prominent than the remaining planes of the same form. Indeed, they were frequently diminished to such an extent that they appeared almost as lines, and then no image could be obtained from them.

Among the crystals which were studied, one only was found doubly terminated. The forms were as follows: —

Analogue Pole.	Antilogue Pole.
$\{110\}$	$k\{211\}$
$\{100\}$	$\{110\}$
$k\{11\bar{1}\}$	$\{100\}$
$k\{31\bar{2}\}$	

One crystal was very highly modified, and exhibited all the forms, with the exception of $\{211\}$.

The following measurements were obtained: Fundamental angle (between normals) (100) and (010) $= 77° 17'$; 77° Dana.

The angle between the axes of Miller's system, 79° 36, or the vertical axes of Naumann's system $c = 0.90146$; 0.89526 Dana.

Angles between normals.	Observed.	Calculated from (100) ∧ (010).	Dana.
$(11\bar{2})$ and (110)	62° 23	62° $30\frac{2}{3}$	62° 40
$(11\bar{2})$ " $(11\bar{1})$	25° 33	25° $39\frac{3}{4}$	25° 49
(110) " (101)	47° 6	47° $7\frac{1}{2}$	46° 52
(110) " (211)	23° 33	23° $33\frac{3}{4}$	23° 26
(110) " (310)	21° 53	21° $47\frac{1}{2}$	

Angles between normals.			Observed.	Calculated from (100) ∧ (010).	Dana.
(110)	"	(21$\bar{1}$)	29° 8	29° 10	29°
(110)	"	(31$\bar{2}$)	41° 51	41° 48	41° 48
(110)	"	(10$\bar{1}$)	66° 16	66° 26$\frac{1}{3}$	66° 34
(31$\bar{2}$)	"	(11$\bar{1}$)	21° 12	21° 19$\frac{1}{3}$	
(11$\bar{2}$)	"	(21$\bar{3}$)	11°	10° 53$\frac{3}{5}$	10° 54
(21$\bar{3}$)	"	(10$\bar{1}$)	19° 7	19° 6$\frac{2}{5}$	19° 6
(10$\bar{1}$)	"	(1$\bar{1}$0)	59° 57	60°	60°

Crystals are stout, and have a section in general triangular. A perfect and easy cleavage parallel to $\{10\bar{1}\}$ can be obtained, the lustre of which is pearly. Prism faces, except sometimes those of $\{21\bar{3}\}$, are remarkable for the absence of striations. The color of the mineral varies slightly: some crystals are almost pure white; others very light amber, and these are transparent. The mean specific gravity of two determinations gave the figures 3.01589. Fuses easily to a white glass, and when decomposed with the mixture of bisulphate of potassium and fluor-spar, imparts to the flame a green color, far more intense than I have previously obtained with Tourmaline.

IODIDE OF ARSENIC.

In 1880 I undertook the study of the physical and chemical properties of iodide of arsenic. Professor J. P. Cooke had previously shown (Proceedings of the American Academy, Vol. XIII.) that solutions of iodide of antimony in bisulphide of carbon were oxidized when exposed to sunlight, provided that air had free access. From the analogy of the properties of arsenic and antimony, it was thought that the iodides of these elements would exhibit the same behavior. My observations in this investigation I have recorded below.

Iodide of arsenic is very easily prepared by shaking up in a flask a solution of iodine in bisulphide of carbon with pulverized arsenic. By repeated crystallizations from bisulphide of carbon, the resulting iodide is purified, and is finally deposited in yellow-red hexagonal tables. Since iodide of arsenic is more soluble in bisulphide of carbon than iodide of antimony, the conditions are more favorable for obtaining large and stout crystals than in the case of SbI_3. Solutions of AsI_3 in bisulphide of carbon are light red, but rapidly change in sunlight, the oxidation closely resembling that of SbI_3. Free iodine is given off, but remains dissolved in the bisulphide of carbon, coloring the solution dark purple. Where the solution of iodide of arsenic has moistened the walls of the flask or containing vessel during the process of oxidation, minute octahedrons of arsenious oxide are deposited. A white deposit is also formed at the botton of the flask, but in quantities too small to test. This deposit is probably As_2O_3. Now, this decomposition, unlike that of SbI_3, is complete, and the chemical reaction may be expressed by the formula, —

$$4\ AsI_3 + O_6 = 2\ As_2O_3 + 6\ I\text{-}I.$$

The reaction for the oxidation of SbI_3 in a similar way, as given in the paper above alluded to, is as follows: —

$$SbI_3 + O = SbOI + I\text{-}I.$$

The oxidation of iodide of arsenic, therefore, goes a step farther, so that instead of oxi-iodide, there is formed an oxide of arsenic.

After the solution has been filtered from the oxide, distilled several times with fresh bisulphide of carbon, and then allowed to crystallize, no new modification of AsI_3 could be detected. In like manner, there is no variety corresponding to the yellow trimetric iodide of antimony. Iodide of arsenic sublimes easily in yellow-red leaves, with an hexagonal outline, which, when examined with the polariscope, exhibit the phenomena of optically uniaxial crystals, with a negative double refraction.

The melting point of iodide of arsenic is $138\frac{1}{2}°$–$139°$, about 28° lower than that of SbI_3 (hexagonal variety), which is given 167°.

Iodide of arsenic crystallizes in the hexagonal system, and is isomorphous with SbI_3 (red variety). The crystals of both substances consist of a rhombohedron modified by the first acute rhombohedron and basal plane, and parallel to this latter form perfect cleavages are very easily obtained. The crystals which I measured were prepared by the method above described, and also by crystallizing a German preparation of the same iodide from bisulphide of carbon.

Forms	{100}	{10$\bar{1}$1}	$+R$	Figs. 5 and 6.
	{110}	{1$\bar{1}$02}	$-\frac{1}{2}R$	
	{111}	{0001}	oP	

Faces of the form {110} were more perfectly developed than those of {100}; in consequence of this the fundamental angle (110) $\wedge$ (111) was taken for calculation. Fundamental angle 110 $\wedge$ 111 = 59° 48′ 27″. The axes of Miller's system make with each other the angle 51° 38′ (54° 40′ for iodide of antimony); the vertical axis of Naumann's system $c = 2.9796$ ($c = 2.769$ for SbI_3). In the following summary of

Fig. 1.

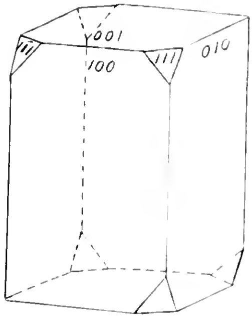


Fig. 2.

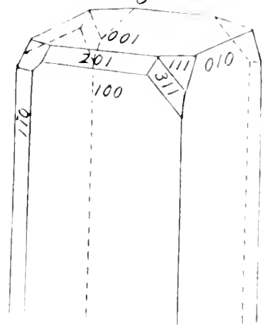


Fig 3.

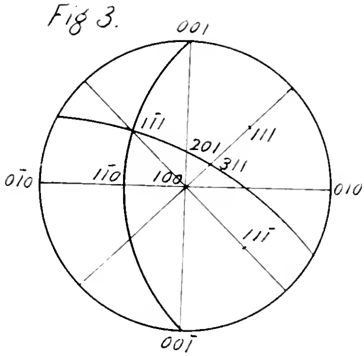


Fig. 4.

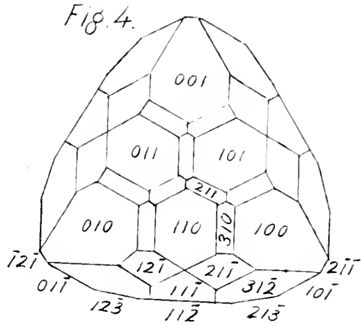


Fig. 5.

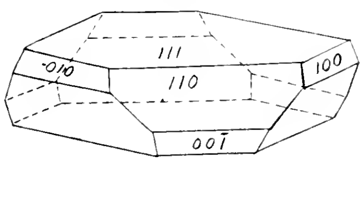
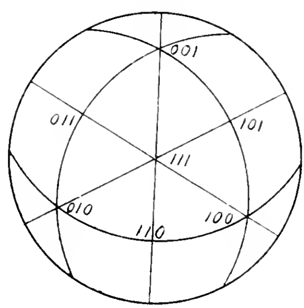


Fig. 6.



angles I have compared those given by P. Friedlander, Zeitsch. f. Kryst. u. Min., iii. 214.

Angles between normals.	Measured.	Calculated.	Friedlander.
(110) and (111)	59° 48′ 27″	. . .	59° 59′
(110) " (00$\bar{1}$)	46° 21′ 50″	46° 24′ 46″	
(00$\bar{1}$) " (111)	73° 50′ 47″	73° 46′ 47″	
(100) " (010)	. . .	112° 31′	
(100) " (110)	. . .	56° 15′ 30″	
(110) " (011)	. . .	96° 55′ 30″	96° 54′ (97° 10′ calculated).

Faces of the form {100} were very frequently striated, but still not enough to materially vitiate the angles obtained from them, as shown by the table.

Twins are very common, the twinning plane parallel to the basal section.

I have in progress a comparison of the three iodides of antimony, arsenic, and bismuth, and the results will be published as soon as crystals of iodide of bismuth can be prepared large enough to measure.

VI.

RESEARCHES ON THE COMPLEX INORGANIC ACIDS.

By Wolcott Gibbs, M. D.,

Rumford Professor in Harvard University.

(Continued from Vol. XVI. p. 139.)

Presented May 24th, 1881.

PHOSPHO-MOLYBDATES.

The application of molybdic oxide to the separation and estimation of phosphoric acid has given a special interest to the phospho-molybdates, and they have accordingly been studied more or less completely by several chemists. The most thorough investigations which we possess are those of Debray,* Rammelsberg,† and Finkener,‡ but particular salts have been examined by others, and these will be noticed under the appropriate special headings.

Phospho-molybdates appear to be formed whenever phosphoric acid or a soluble phosphate is brought into solution with a molybdate, the presence of a free acid not being essential. They are also formed when phosphates and molybdates are fused together, when molybdates insoluble in water are dissolved in phosphoric acid, when molybdic oxide is digested with an alkaline phosphate, and when insoluble phosphates and molybdates are treated together with a dilute acid. As a class, they are better defined and more easy to obtain pure than the phospho-tungstates which in many respects they closely resemble. When phospho-molybdates of fixed alkaline bases are heated, they at first give off water of crystallization, and by careful heating may be obtained anhydrous. In some cases, however, molybdic oxide is volatilized even from salts containing fixed alkaline bases.

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* Bull. Soc. Chim., [2.] v. 404.

† Berichte der Deutschen Chem. Gesellschaft, Zehnter Jahrgang, p. 1776.

‡ Ibid., Elfter Jahrgang, p. 1638.

I did not succeed in obtaining well-defined pyro-phospho-molybdates or pyro-phospho-tungstates, though of course the residues of the ignition of the acid salts may be regarded as such. When a phospho-molybdate is dissolved in ammonia-water and a current of sulphydric acid gas is passed into the hot solution, sulpho-molybdates are formed in large quantity. This reaction distinguishes the phospho-molybdates from the phospho-tungstates which are not decomposed under the same circumstances.

Analytical Methods. — The determination of the sum of the percentages of molybdic and phosphoric oxides was usually effected, as in the case of the phospho-tungstates, by precipitating the two oxides together by mercurous nitrate with addition of mercuric oxide to neutralize the free nitric acid. It is best to precipitate from a boiling solution, and to boil for a short time after adding mercuric oxide. This last must always be in small excess. On account of the volatility of molybdic teroxide, it is not possible to determine directly the sum of the weights of the two oxides by simple ignition, but the difficulty may be readily overcome by the following process. The filter with the mercurous salts is to be cautiously heated in a platinum crucible properly inclined to the vertical axis of the flame until the filter is completely carbonized. On then regulating the heat and the supply of air, the carbon may be readily burned off, leaving a mass of mercurous salts mixed with more or less mercuric oxide, no weighable amount of molybdic teroxide being lost. An accurately weighed quantity of anhydrous normal sodic tungstate in fine powder is then to be added, and the contents of the crucible carefully mixed together with a stout platinum wire previously weighed with the crucible itself. The whole is to be heated at first by radiation from a small iron dish, and afterward directly, until a clear white fused mass is obtained. A second ignition and second weighing will determine whether every trace of mercury has been expelled. It is almost needless to remark, that all these operations must be conducted under a flue with a good draught. This process gives excellent results, and is much less tedious than would perhaps be supposed.

After the estimation of the phosphoric oxide the molybdic teroxide is best determined by difference from the sum of the weights of the two oxides found as above. No really good general method for the quantitative separation and estimation of molybdic oxide has yet been given, at least no one which is sufficiently accurate to serve as a check upon the method above described. The ammonium salts of this series are most simply analyzed by igniting them directly with sodic tungstate, when the loss of weight corresponds to the sum of the water and ammonia.

As in the case of the phospho-tungstates, the quantitative determination of phosphoric oxide is a matter of considerable difficulty. The method of separation by means of magnesia mixture has been carefully studied by Dr. Gooch, to whose paper I have already referred.* Dr. Gooch found it necessary to precipitate the ammonio-magnesic phosphate a second time, a single precipitation giving an error amounting sometimes to 6 or 7% of the phosphoric acid present. After re-solution and precipitation by ammonia, the mean error amounted to only 0.65%, which makes an almost insensible correction when the quantity of phosphoric oxide is small. In a few instances I have applied this correction after a double precipitation, but I prefer to employ the following method, which gives an almost perfect separation from molybdic teroxide. The phosphoric oxide is first precipitated from a hot solution as ammonio-magnesic phosphate, the supernatant liquid after complete subsidence carefully decanted upon an asbestos filter, the precipitate washed with magnesia mixture and ammonia, then redissolved in the least possible quantity of hot dilute chlorhydric acid and reprecipitated with ammonia. After complete subsidence and decantation, the precipitate is boiled with successive portions of a solution of ammonic sulphide. A more or less dark orange-red solution of ammonic sulpho-molybdate is always obtained at first, but after two or three repetitions of the process the ammonic sulphide added remains colorless on heating. The ammonio-magnesian phosphate is then filtered upon the asbestos filter already employed. In place of this method I have sometimes employed the following modification, which gives, I think, equally good results. After the first precipitation the phosphate is to be redissolved, and the hot solution precipitated at once by ammonic sulphide in excess. The precipitated phosphate is then to be boiled two or three times with ammonic sulphide as above. Whatever inaccuracy is inherent in this method depends, in my judgment, upon the fact that, as Dr. Gooch has shown, the determination of phosphoric acid by means of magnesia is, under the most favorable circumstances, a less accurate process than has been supposed.

The determination of ammonia and the alkalies was effected by the methods already described in the case of the phospho-tungstates. Water must be estimated by ignition with sodic tungstate, as there is

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* Proceedings of American Academy, Vol. XV. p. 53.

often volatilization of molybdic teroxide when a phospho-molybdate is ignited at a temperature sufficient to expel its water. The analyses require great care and no small amount of practice to insure good results. As in the case of the phospho-tungstates, the alkaline bases are best determined by difference.

Twenty-four Atom Series. — Phospho-molybdic acid. The acid of this series was first obtained by Debray, who prepared it by boiling ammonic phospho-molybdate with nitro-muriatic acid, and allowing the solution to evaporate spontaneously. I find that this is a good method of obtaining the acid, but the following details should be observed. The bright yellow ammonic phospho-molybdate should be first dried, and then heated with a large excess of strong aqua-regia in a casserole over an iron capsule to serve as a radiator. In this manner the decomposition proceeds very regularly and without succussions. When it becomes necessary to add fresh acid, the supernatant liquid should be allowed to settle completely and then be poured off carefully. Fresh acid may then be added, and the process, which is at best a slow one, continued. When the ammonium salt has disappeared, the liquid is to be evaporated until the excess of nitric and chlorhydric acids has been expelled. On standing, large bright yellow octahedral crystals are obtained from the very concentrated solution. These may be redissolved and recrystallized, but there is always some loss in the process of purification, because solution in water produces more or less decomposition of the acid with formation of a pale greenish white crystalline body. This substance passes very readily through a filter, and the solution of the acid must be allowed to settle completely before the clear supernatant liquid is brought upon the filter. Debray obtained three different hydrates of phospho-molybdic acid, to which he gave, respectively, the formulas

$$20\ MoO_3 \cdot P_2O_5 \cdot 3\ H_2O + 21\ aq,$$

$$20\ MoO_3 \cdot P_2O_5 \cdot 3\ H_2O + 48\ aq,$$

and

$$20\ MoO_3 \cdot P_2O_5 \cdot 3\ H_2O + 38\ aq.$$

Unfortunately he has not given either the methods or the complete results of his analyses. In the first hydrate he found 13.30%, in the second 23.40%, and in the the third 19.60% of water.

I obtained the acid only in transparent octahedral crystals which had a bright yellow color. Of these crystals, dried by pressure with woollen paper,

0.9945 gr. lost by ignition with WO_4Na_2 0.2362 gr. = 23.75% water.
1.4588 gr. gave 0.0713 gr. $P_2O_7Mg_2$ = 3.12% P_2O_5.

The analysis leads to the formula

$$24\ MoO_3 \,.\, P_2O_5 \,.\, 3\ H_2O + 59\ aq,$$

which requires: —

		Calc'd.	Found.
24 MoO_3	3456	73.31	73.13
P_2O_5	142	3.01	3.12
62 H_2O	1116	23.68	23.75
	4714	100.00	

The phosphoric oxide was determined by double precipitation and treatment with ammonic sulphide. The molybdic oxide was estimated by difference. The crystallized acid effloresces so readily that the precise determination of the water is difficult. In a portion of the crystals which had effloresced in a very marked degree, —

0.9873 gr. lost on ignition with WO_4Na_2 0.1760 gr. = 17.82% water
2.2472 gr. gave 0.1163 gr. $P_2O_7Mg_2$ = 3.31% P_2O_5

The ratio of the molybdic to the phosphoric oxide is in this analysis also 24 : 1; and, if we compute the results of both analyses for an anhydrous compound of the two oxides, we find: —

		Calc'd.		
24 MoO_3	3456	96.06	95.91	95.97
P_2O_5	142	3.94	4.09	4.03
	3598	100.00	100.00	100.00

The analyses leave, I think, no reasonable doubt as to the ratio of the two oxides. Phospho-molybdic acid therefore corresponds in composition with phospho-tungstic acid, the ratio of the two oxides being 24 : 1, as given by Finkener,* and not 20 : 1, as stated by Debray. With respect, however, to the number of atoms of water in the crystallized octahedral hydrate, I may remark that, while the analysis agrees best with the formula given,

$$24\ MoO_3 \,.\, P_2O_5 \,.\, 3\ H_2O + 59\ aq,$$

* *Loc. cit.*

it is much more probable that the acid really contains an atom less of water, and that its formula, apart from the question of basicity, is

$$24\ MoO_3 \,.\, P_2O_5 \,.\, 6\ H_2O + 55\ aq,$$

like

$$24\ WO_3 \,.\, P_2O_5 \,.\, 6\ H_2O + 55\ aq,$$

already described. This formula requires 23.38% water, instead of 23.75%, as found. Debray found 23.10%. As already stated, the crystals analyzed were dried by pressure with woollen paper, after draining off a syrupy mother liquor, and may therefore not have been perfectly free from extraneous water. Finally, the analyses of Finkener led also to the formula with 61 atoms of water, and I shall adopt this as the definite constitution of the octahedral hydrate. Finkener's work has not yet been published in detail; but from the abstract which he has given, it clearly appears that we owe to him the establishment of the true constitution of the only phospho-molybdic acid yet obtained. As already mentioned, there are two other hydrates of phospho-tungstic acid, having, respectively, the formulas

$$24\ WO_3 \,.\, P_2O_5 \,.\, 6\ H_2O + 47\ aq,$$

and

$$24\ WO_3 \,.\, P_2O_5 \,.\, 6\ H_2O + 34\ aq.$$

The two hydrates of phospho-molybdic acid described by Debray would correspond to the formulas

$$24\ MoO_3 \,.\, P_2O_5 \,.\, 6\ H_2O + 24\ aq,$$

and

$$24\ MoO_3 \,.\, P_2O_5 \,.\, 6\ H_2O + 43\ aq,$$

if we suppose them, as is most probable, to belong to the 24-atom series. The first formula requires 13.05%, the second 19.66% water; Debray found 13.09% and 19.60%. Finkener obtained still another hydrate, containing about 32 atoms of water, basic water included.

Phospho-molybdic acid dissolves very readily in water, forming a colorless liquid which has a strong acid reaction. As already stated, the solution is always accompanied by a slight decomposition, with formation of a very pale greenish white crystalline substance. A precisely similar decomposition is observed in the solution of the corresponding phospho-tungstic acid. The crystals lose all their water when slightly ignited. According to Finkener, three atoms of water remain at 140° C. The solution readily expels carbonic dioxide from the alkaline carbonates. The question of the basicity of the acid will be discussed farther on.

24 : 3 *Ammonic Phospho-molybdate.* — The constitution of the beautiful yellow salt which is formed when an excess of a mineral acid is added to a solution containing molybdic and phosphoric oxides and a salt of ammonium, has long been in dispute. The analyses of Svanberg and Struve,* Nutzinger,† Sonnenschein,‡ Lipowitz,§ and Seligsohn,‖ gave results which differed very sensibly from each other, according to the method of analysis employed. Debray gave the formula

$$20\ MoO_3 \cdot P_2O_5 \cdot 3\ (NH_4)_2O + 3\ aq,$$

but without the details of his analysis. More recently the subject has been examined with great care by Finkener,¶ who has arrived at the conclusion that, though the percentages of water and ammonia may vary within wide limits, the ratio of the molybdic and phosphoric oxides is always as 24 : 1.

With respect to the preparation and properties of the yellow ammonium salt, I have little to add to what has been done by these chemists. I repeatedly prepared the salt for analysis, usually by mixing solutions of ammonic molybdate — 7 : 3 salt — and phosphate, adding nitric acid in excess to the solution, and boiling. When the mixed solution is boiled for a short time, the precipitation of the yellow salt is complete after standing until the liquid becomes cold. In the publication of this result, which is important in analysis, I have been anticipated by Atterberg;** but I propose in another paper to give the results of my work on the quantitative determination of phosphoric acid, and will then give ample details.

As regards the composition of the yellow phospho-molybdates of ammonium, my results do not agree with those of Finkener, as I think I have evidence that, as in the case of the phospho-tungstates, there are series of phospho-molybdates in which the ratio of the molybdic to the phosphoric oxide is as 20 : 1, as 22 : 1, and as 24 : 1. In one preparation, —

1.1492 gr. lost on ignition with WO_4Na_2 0.0827 gr. NH_3 and H_2O = 7.20%

* Journal für prakt. Chemie, xliv. 291.
† Pharmaceut. Vierteljahresschrift, iv. 549.
‡ Journal für prakt. Chemie, liii. 342.
§ Poggendorff's Annalen, cix. 135.
‖ Journal für prakt. Chemie, lxvii. 470.
¶ *Loc cit.*
** Berichte der Chem. Gesellschaft, 1881, p. 1217.

0.5905 gr. lost on ignition with WO_4Na_2 0.0432 gr. NH_3 and H_2O $= 7.31\%$
1.7158 gr. gave 0.1027 gr. $P_2O_7Mg_2 = 3.83\%$ P_2O_5
0.9806 gr. " 0.0567 gr. $P_2O_7Mg_2 = 3.70\%$ P_2O_5
1.8903 gr. " 0.1321 gr. NH_4Cl $= 3.20\%$ $(NH_4)_2O$

In these analyses, the first determination of the phosphoric oxide was made by double precipitation only, without subsequent treatment with ammonic sulphide; but in the second, this reagent was employed in the manner above described. The ratio of MoO_3 to P_2O_5 is almost precisely 24 : 1, and the analyses correspond closely with the formula

$$24\ MoO_3 . P_2O_5 . 3\ (NH_4)_2O + 24\ MoO_3 . P_2O_5 . 2\ (NH_4)_2O . H_2O + 16\ aq,$$

which requires: —

		Calc'd.	Mean.		
48 MoO_3	6912	89.05	89.00	——	——
2 P_2O_5	284	3.66	3.75	3.70	3.83
5 $(NH_4)_2O$	260	3.35	3.39	3.39	
17 H_2O	306	3.94	3.86	3.81	3.92
	7762	100.00	100.00		

Acid salts of similar type occur frequently in the class of phospho-molybdates, as in that of phospho-tungstates.

24 : 1 *Croceo-cobalt Salt.* — The disposition of the cobaltamines to form highly crystalline compounds, together with their well-defined and various degrees of basicity, led me to study the relations of these bases to the phospho-molybdic acids. This had already been done to a certain extent with the 5 : 1 atom series by Jörgensen, whose results I shall cite in connection with that series. Neither roseo-cobalt nor luteo-cobalt forms well-defined salts with 24 : 1 phospho-molybdic acid. I had therefore recourse to croceo-cobalt,* the oxide of which may be written

$$Co_2(NH_3)_8(NO_2)_4O, \text{ or, briefly, } CcO.$$

The chloride of this series gives no precipitate with solutions of 7 : 3 ammonic molybdate, or of hydro-disodic phosphate; but in an acid solution of these two salts a solution of the chloride throws down a beautiful bright yellow highly crystalline salt, which may be washed with cold water. The portion analyzed was dried on woollen paper only. Of this salt, —

* Proceedings of American Academy, Vol. X. p. 1.

1.0728 gr. gave 0.8133 gr. $MoO_3 + P_2O_5$ = 75.81%
1.4520 gr. " 0.4719 gr. P_2O_5 = 2.96%

This corresponds to 72.85% MoO_3 by difference, and 24.19% of CeO and water by the loss. The analyses agree very closely with the formula

$$24\ MoO_3 . P_2O_5 . CeO . 2\ H_2O + 21\ aq,$$

which requires: —

		Calc'd.		
24 MoO_3	3456	72.82		72.86
P_2O_5	142	2.99		2.96
CeO	734	15.47	24.19	24.19
23 H_2O	414	8.72		
	4746	100.00		

Under the microscope this salt is seen to consist of fine yellow felted needles. It is very slightly soluble in cold water, but is soluble in a rather large quantity of boiling water, giving an orange-yellow solution, with a strongly acid reaction. The solution gives with argentic nitrate a very insoluble sulphur-yellow flocky precipitate, which after a time becomes crystalline, and a pale yellow flocky precipitate with mercurous nitrate. No precipitate is formed with cupric sulphate or baric chloride. The salt could not be recrystallized; it is interesting as a particularly well-defined soluble acid salt of the 24 : 1 atom series.

24 : 2 *Acid Potassium Salt.* — This salt was prepared by boiling together solutions of potassic molybdate and phosphate, adding an excess of nitric acid, and boiling the whole for some time. As in the case of the ammonium salts, the precipitation is greatly facilitated by this process, taking place very slowly in the cold. The salt obtained was in very minute crystals, bright yellow, and but slightly soluble in cold water. Of this salt, —

0.7772 gr. lost on ignition 0.0128 gr. = 1.64% water
0.7962 gr. " " 0.0130 gr. = 1.66% "
1.1703 gr. gave 1.0895 gr. $MoO_3 + P_2O_5$ = 93.10%
1.3263 gr. " 0.0779 gr. $P_2O_7Mg_2$ = 3.76% P_2O_5
1.3033 gr. " 0.0778 gr. " = 3.82% "

The phosphoric oxide was twice precipitated as ammonio-magnesic phosphate. The analyses correspond with the formula

$$24\ MoO_3 . P_2O_5 . 2\ K_2O . H_2O + 3\ aq,$$

which requires: —

		Calc'd.			
24 MoO_3	3456	89.55		89.31	
P_2O_5	142	3.69	3.76		3.82
2 K_2O	189	4.90		5.25	
4 H_2O	72	1.86	1.66		1.64
	3859	100.00			

Twenty-two Atom Series. — In the paper already referred to, Rammelsberg has described several salts in which he found the ratio of molybdic to phosphoric oxide as 22 : 1. Unfortunately, he has not given the method of analysis which he employed, and in a question of so much difficulty and delicacy it is, to say the least, extremely desirable to know what degree of precision may be expected in the analyses. As his results appear to be supported by my own, I shall adopt them, leaving to the further progress of analytical chemistry the final settlement of the few doubtful points.

22 : 3 *Ammonium Salt.* — Rammelsberg found for the neutral salt of this series the formula

$$22\ MoO_3 \cdot P_2O_5 \cdot 3\ (NH_4)_2O + 12\ aq,$$

which corresponds, except as regards the amount of water of crystallization, with a phospho-tungstate which I have already described, —

$$22\ WO_3 \cdot P_2O_5 \cdot 3\ (NH_4)_2O + 21\ aq.$$

In one preparation of a yellow insoluble ammonium salt exactly resembling the corresponding salt of the 24-atom series, —

1.6885 gr., lost on ignition with WO_4Na_2 0.0873 gr. = 5.17% NH_3 and H_2O

1.7764 gr. gave 0.6200 gr. $P_2O_7Mg_2$ = 4.17% P_2O_5.

1.9024 gr. " 0.6029 gr. " = 4.01% "

1.2334 gr. " 0.6262 gr. NH_4Cl = 4.23% $(NH_4)_2O$.

The salt was dried for some time *in pleno* over sulphuric acid, and had evidently lost water of crystallization. If we deduct the remaining water, 0.94%, and calculate the analysis for an anhydrous salt, we have for the formula

$$22\ MoO_3 \cdot P_2O_5 \cdot 3\ (NH_4)_2O\,;$$

		Calc'd.	
22 MoO_3	3168	91.41	91.68
P_2O_5	142	4.09	4.05
3 $(NH_4)_2O$	156	4.50	4.27
	3466	100.00	

In another preparation, —

1.0324 gr. lost on ignition with WO_4Na_2 0.0922 gr. = 8.93% NH_3 and H_2O

2.0670 gr. gave 0.1255 gr. $P_2O_7Mg_2$ = 3.88% P_2O_5

2.0352 gr. " 0.1220 gr. " = 3.84% "

These analyses lead to the formula

$$22\ MoO_3 . P_2O_5 . 3\ (NH_4)_2O + 9\ aq,$$

which requires: —

		Calc'd.			
22 MoO_3	3168	87.32		87.21	
P_2O_5	142	3.91	3.88		3.84
3 $(NH_4)_2O$	156	4.29 } 8.77		8.93	
9 H_2O	162	4.48 }			
	3628	100.00			

If from the analyses of the two salts above described we calculate the composition of the combination of molybdic and phosphoric oxides supposed to be isolated, and compare this with the percentages calculated upon the two hypotheses of a ratio of 22 : 1 and a ratio of 24 : 1, we have: —

		Calc'd.	I.	II.	Calc'd.		
22 MoO_3	3168	95.76	95.76	95.76	96.06	3456	24 MoO_3
P_2O_5	142	4.24	4.24	4.24	3.94	142	P_2O_5
	3310	100.00	100.00	100.00	100.00	3598	

In both cases the phosphoric oxide was precipitated twice, but the ammonia-magnesian phosphate was not treated with ammonic sulphide. According to the results of Dr. Gooch already cited, the probable error of this method does not exceed 1% in excess of the quantity of phosphoric oxide present. It appears, therefore, that the correction to be applied to the phosphoric oxide in the above analyses does not, at most, exceed 0.04%. The mean of Dr. Gooch's analyses would require a deduction of 0.02% only. The yellow ammonium salt analyzed by Rammelsberg corresponds to the formula

$$22\ MoO_3 . P_2O_5 . 3\ (NH_4)_2O + 12\ aq,$$

which requires (Rammelsberg): —

		Calc'd.	
22 MoO_3	3168	86.04	86.45
P_2O_5	142	3.86	3.90
3 $(NH_4)_2O$	156	4.24	3.25
12 H_2O	216	5.86	5.77
	3682	100.00	99.37

Rammelsberg gives these figures as the means of several analyses which agree well with each other, but it must be admitted that a closer correspondence with the percentages required by the formulas would have been desirable. The comparison is not given in his paper. The air-dried salt loses all its water over sulphuric acid. The three atoms of basic water, if we assume their existence, must therefore be united by a very feeble affinity. Rammelsberg has also analyzed the corresponding potassic salt of the same series. I here give his results, for the sake of comparison with the formula: —

		Calc'd.	
22 MoO_3	3168	83.17	84.43
P_2O_5	142	3.73	3.78
3 K_2O	283	7.43	6.86
12 H_2O	216	5.67	5.55
	3809	100.00	100.62

This salt loses all its water between 120° and 140°. In judging the results of these analyses, as well as of those which I have given, it must be carefully borne in mind that the salts themselves cannot be recrystallized, and that consequently their absolute purity cannot be guaranteed. Moreover, if — as I believe I have shown — there are very similar salts which represent three series in which the ratios of the molybdic and phosphoric oxides are respectively as 24 : 1, 22 : 1, and 20 : 1, we may, at least occasionally, have mixtures of the salts of three. or of any two series. The difficulty here is precisely that which occurs in the case of the phospho-tungstates.

44 : 2 *Acid Potassium Salt.* — This salt was prepared by boiling a mixture of potassic molybdate and phosphate with nitric acid in excess, when a beautiful yellow crystalline powder separated. This was washed with cold water and dried on woollen paper. Of this salt, —

0.9850 gr. lost on ignition 0.0521 gr. = 5.28% water.
0.8983 gr. gave 0.7943 gr. $MoO_3 + P_2O_5$ = 88.42%
2.0617 gr. gave 0.1201 gr. $P_2O_7Mg_2$ = 3.72%

These analyses lead to the formula

$$44\ MoO_3 \,.\, 2\ P_2O_5 \,.\, 5\ K_2O \,.\, H_2O + 21\ aq,$$

or

$$22\ MoO_3 \,.\, P_2O_5 \,.\, 3\ K_2O + 22\ MoO_3 \,.\, P_2O_5 \,.\, 2\ K_2O \,.\, H_2O + 21\ aq,$$

which requires: —

		Calc'd.	
44 MoO_3	6336	84.62	84.70
2 P_2O_5	284	3.79	3.72
5 K_2O	472	6.30	6.30 (diff.)
22 H_2O	396	5.29	5.28
	7488	100.00	

The salt is therefore the acid salt corresponding to a neutral salt with the formula

$$22\ MoO_3 \cdot P_2O_5 \cdot 3\ K_2O.$$

Rammelsberg's analyses agree better with the formula of the acid salt given above than with that of the neutral compound assumed by him.

Twenty Atom Series. — The only salt of this series which I have obtained is one of ammonium prepared like the salts already described, having like these a fine yellow color and a very fine-grained crystalline structure, and like them but slightly soluble in water. Of this salt, —

1.0936 gr. lost on ignition with WO_4Na_2 0.0729 gr. = 6.66% NH_3 and H_2O
1.8183 gr. lost on ignition with WO_4Na_2 0.1155 gr. = 6.35% NH_3 and H_2O
0.8862 gr. gave 0.6153 gr. NH_4Cl = 4.12% $(NH_4)_2O$
1.3213 gr. gave 0.6224 gr. $P_2O_7Mg_2$ = 4.19% P_2O_5
1.5135 gr. gave 0.6349 gr. $P_2O_7Mg_2$ = 4.31% P_2O_5

The salt was dried on a water-bath, and afterward over sulphuric acid. The phosphoric oxide was precipitated twice, but not treated with ammonic sulphide. The analyses lead to the formula

$$60\ MoO_3 \cdot 3\ P_2O_5 \cdot 8\ (NH_4)_2O \cdot H_2O + 11\ aq.$$

which requires: —

		Calc'd.				
60 MoO_3	8640	89.09	93.48		89.21	93.52
3 P_2O_5	426	4.39		4.31	4.19	
8 $(NH_4)_2O$	416	4.29	6.52		4.12	6.50
12 H_2O	216	2.23			2.54	
	9698	100.00				

If we calculate the composition of the mixed oxides of molybdenum and phosphorus existing in this salt we have: —

		Calc'd.	
20 MoO_3	2880	95.30	95.39
P_2O_5	142	4.70	4.61
	3022	100.00	100.00

It will be seen that the ratio is here very nearly as 20 : 1. This may however be merely accidental, and farther researches are necessary to fully establish the existence of a 20-atom series.

According to Debray a solution of argentic nitrate gives with one of phospho-molybdic acid a precipitate which soon becomes crystalline, and which has the formula

$$20\ MoO_3 \cdot P_2O_5 \cdot 7\ Ag_2O + 24\ aq.$$

Such a salt would possess a twofold interest, first, as another evidence of the existence of a 20-atom series of phospho-molybdates, and, secondly, as showing that the acid of the series may unite with more than *six* atoms of base. On mixing the two solutions as above, I obtained a precipitate in small indistinct crystals of a greenish yellow color. These crystals were soluble in hot water, but the solution was quickly decomposed with precipitation of a white powder. Under the microscope with a high power and transmitted light the salt appeared to consist of small tabular crystals mixed with a few long yellow prisms of very different habitus. Of this compound, —

1.3604 gr. lost by ignition with WO_4Na_2 0.0692 gr. water = 5.08%
2.1099 gr. gave 0.8287 gr. AgCl = 31.63% Ag_2O
0.6733 gr. gave 0.2619 gr. AgCl = 31.44% Ag_2O
2.1099 gr. gave 0.0928 gr. $P_2O_7Mg_2$ = 2.81% P_2O_5

The phosphoric oxide was determined in the filtrate from the argentic chloride by double precipitation and treatment with ammonic sulphide. The ratio of the molybdic to the phosphoric oxide is as 21 : 1, but the formula which most nearly represents the analysis is

$$22\ MoO_3 \cdot P_2O_5 \cdot 7\ Ag_2O + 14\ aq,$$

which requires, —

		Calc'd.		
22 MoO_3	3168	61.08	60.57	
P_2O_5	142	2.74	2.81	
7 Ag_2O	1624	31.32	31.44	31.63
14 H_2O	252	4.86	5.08	
	5186	100.00		

The only conclusion which can fairly be drawn from the analysis is that there is at least one phospho-molybdate in which the number of atoms of base exceeds three. It is certain that the salt does not represent a perfectly definite and homogeneous compound, and it may possibly be a mixture of the 20-atom salt, $20\,MoO_3 . P_2O_5 . 6\,Ag_2O$, and an acid molybdate of silver, $2\,MoO_3 . Ag_2O$, nearly in atomic proportions. By dissolving the salt in nitric acid and evaporating, Debray obtained another salt in small brilliant yellow crystals. For this salt he proposes the formula

$$20\,MoO_3 . P_2O_5 . 2\,Ag_2O + 7\,aq,$$

but as usual he has given no analyses.

Eighteen Atom Series. — I have myself met with no salts belonging to this series, but according to Finkener* there are sodium salts corresponding to the general formula

$$18\,MoO_3 . P_2O_5\ (3 - x)\ Na_2O + (25 + x)\ aq.$$

These salts are yellow and easily soluble.

Sixteen Atom Series. — 16 : 3 *Ammonium Salt.* — In preparing the 5 : 3 atom ammonium salt a white crystalline precipitate was formed, insoluble in cold, but soluble with decomposition in much boiling water, and easily soluble in ammonia. In this salt dried over sulphuric acid, —

0.5100 gr. lost by ignition with WO_4Na_2 0.0722 gr. = 14.16% NH_3 and H_2O
1.1653 gr. gave 0.1259 gr. NH_4Cl = 5.25% $(NH_4)_2O$
0.8114 gr. gave 0.0658 gr. $P_2O_7Mg_2$ = 5.19% P^2O_5

The analysis corresponds with the formula

$$16\,MoO_3 . P_2O_5 . 3\,(NH_4)_2O + 14\,aq,$$

which requires, —

		Calc'd.	Found.
16 MoO_3	2304	80.73	80.65
P_2O_5	142	4.97	5.19
3 $(NH_4)_2O$	156	5.46	5.25
14 H_2O	252	8.84	8.91
	2854	100.00	

* *Loc. cit.*, p. 1639.

Five to One Series. — Salts of this series were discovered at an early period in the history of the subject by Zenker.* The ammonium salt was analyzed by Zenker † and Wernecke,‡ and recently by Rammelsberg.§ Debray obtained the same salt, but has published no analyses. Rammelsberg also obtained the corresponding potassium salt, as well as an acid salt of the same series. The alkaline salts are colorless, and separate in well-defined crystals, which are usually easily soluble in water. The acid of the series, as Debray has stated, cannot be obtained by the decomposition of its salts, being resolved by acids into free phosphoric acid and salts of the 24-atom series. The decomposition may probably be expressed by the equation

$$24\,(5\,MoO_3\,.\,P_2O_5\,.\,3\,H_2O) = 5\,(24\,MoO_3\,.\,P_2O_5\,.\,3\,H_2O) + 19\,(P_2O_5\,.\,3\,H_2O).$$

All the neutral salts are tribasic (old style) or more correctly hexatomic, but well-defined acid salts exist in which the ratio of the molybdic oxide to the fixed base is as 10 : 5. Such salts have been obtained by Rammelsberg and by myself. The salts of the higher series are decomposed by alkalies, as stated by Debray, salts of the 5-atom series and alkaline molybdates being formed. Conversely, when a mineral acid is added to a solution of an alkaline salt of the 5-atom series, a salt of a higher series is formed, frequently as a yellow crystalline precipitate. The neutral salts of this series hitherto described have respectively the formulas

$$5\,MoO_3\,.\,P_2O_5\,.\,3\,K_2O + 7\,aq.$$
$$5\,MoO_3\,.\,P_2O_5\,.\,3\,(NH_4)_2O + 7\,aq.$$
$$5\,MoO_3\,.\,P_2O_5\,.\,3\,Na_2O + 14\,aq.$$
$$5\,MoO_3\,.\,P_2O_5\,.\,3\,Ag_2O + 7\,aq.$$

5 : 3 *Phospho-molybdate of Ammonium.* — This beautiful salt appears, as already stated, to have been first obtained by Zenker. It is readily obtained by dissolving together five molecules of ammonic molybdate and two of ammonic phosphate, and evaporating the solution, when beautiful prismatic crystals, with a glassy lustre, separate. These may easily be purified by recrystallization. The salt is readily soluble in hot, less easily in cold water. The solution has an acid reaction. Zenker's analyses, as well as those of Wernecke, agree closely with the formula

$$5\,MoO_3\,.\,P_2O_5\,.\,3\,(NH_4)_2O + 7\,aq,$$

* Journal für prakt. Chemie, lviii. 256.
† *Loc. cit.*
‡ Zeitschrift für Analyt. Chemie, xiv. 12.
§ *Loc. cit.*

in which formula the phospho-molybdic acid is regarded as tribasic. Debray gives the same formula, without details of analysis, and Rammelsberg has very recently again analyzed the salt, confirming the results of Zenker. The salt in question is particularly interesting, first, because the number of atoms of molybdic oxide is *uneven;* and secondly, because the basicity of the acid appears to be 3, and not 6, even when the salt has separated from neutral solutions.

Jörgensen * has described two well-defined crystalline salts belonging to this series and having according to his notation respectively the formulas

$$Co_2\,(NH_3)_{10}Cl_2\,.\,(5\;MoO_3\,.\,2\;PO_4H)$$

and

$$Co_2(NH_3)_{10}Cl_2\,.\,(5\;MoO_3\,.\,2\;PO_4NH_4).$$

I should write these

$$5\;MoO_3\,.\,P_2O_5\,.\,Co_2(NH_3)_{10}Cl_2O_2\,.\,H_2O$$

and

$$5\;MoO_3\,.\,P_2O_5\,.\,Co_2(NH_3)_{10}Cl_2O_2(NH_4)_2O.$$

It will readily be seen that both salts correspond to the acid represented by the formula

$$5\;MoO_3\,.\,P_2O_5\,.\,3\;H_2O.$$

Acid 10 : 5 *Ammonium Salt.* — When ammonic phosphate is dissolved in boiling water, and molybdic oxide is added in small portions at a time, the oxide readily dissolves, but a greater or less quantity of a white insoluble crystalline salt is formed. The filtrate deposits on evaporation large colorless crystals, which appear to be either trimetric or monoclinic. Of these crystals, —

1.1126 gr.	lost on ignition with WO_4Na_2		0.2076 gr.	= 18.66%	NH_3 and H_2O.
1.2962 gr.	"	" "	0.2425 gr.	= 18.71%	"
1.2165 gr.	"	" "	0.2247 gr.	= 18.47%	"
0.9263 gr.	gave	0.1912 gr. $P_2O_7Mg_2$		= 13.20%	P_2O_5
1.0540 gr.	"	0.2196 gr. "		= 13.32%	"
1.1824 gr.	"	0.3018 gr. NH_4Cl		= 12.41%	$(NH_4)_2O$
1.0183 gr.	"	0.2563 gr. "		= 12.23%	"
1.6430 gr.	"	0.4168 gr. "		= 12.32%	"

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* Journal für prakt. Chemie, [2.] xviii. 209.

The analyses lead to the formula

$$10\ MoO_3 . 2\ P_2O_5 . 5\ (NH_4)_2O . H_2O + 6\ aq.$$

or

$$5\ MoO_3 . P_2O_5 . 3\ (NH_4)_2O + 5\ MoO_3 . P_2O_5 . 2\ (NH_4)_2O . H_2O + 6\ aq,$$

which requires: —

		Calc'd.	Mean.			
10 MoO_3	1440	68.24	68.13	...	...	...
2 P_2O_5	284	13.46	13.26	13.20	13.32	...
5 $(NH_4)_2O$	260	12.32	12.32	12.41	12.23	12.32
7 H_2O	126	5.98	6.29	6.15	6.34	6.39
	2110	100.00				

The phosphoric oxide was determined by double precipitation only, without subsequent treatment with ammonic sulphide. The percentage is a little lower than that required by the formula, which is unusual; but the general agreement of the analyses with the formula is satisfactory. Rammelsberg has described an acid potassium salt with the formula

$$10\ MoO_3 . P_2O_5 . 5\ K_2O . H_2O + 19\ aq.$$

It is therefore at least probable that we shall find another ammonia salt with 20 atoms of water, and another potassium salt with 7 atoms. Zenker has described another potassic salt to which he gives the formula, — as I should write it, —

$$9\ MoO_3 . P_2O_5 . 4\ K_2O . 2\ H_2O + 18\ aq;$$

but the results of his analyses differ very widely from the percentages required by the formula, and on repeating his process I obtained only the 10 : 5 atom salt of Rammelsberg. The formula given above for this salt requires 11.11% P_2O_5. I found 11.22%.

Rammelsberg * has also described a white insoluble potassium salt to which he gives the formula 15 $MoO_3 . P_2O_5 . 5\ K_2O$, but without any statement of his analyses.

ARSENIO-MOLYBDATES.

Compounds of arsenic and molybdic oxides have been described by Seyberth † and by Debray.‡ Seyberth obtained an acid with the formula, — as I should write it, —

* *Loc. cit.*

† Berichte der Chem. Gesellschaft, 1874, p. 391.

‡ Comptes Rendus, lxxviii. 1408.

$$7\ MoO_3\ As_2O_5 . 3\ H_2O + 11\ aq,$$

and the three corresponding salts: —

$$7\ MoO_3 . As_2O_5 . (NH_4)_2O . 2\ H_2O + 4\ H_2O$$
$$7\ MoO_3 . As_2O_5 . 3\ BaO$$
$$7\ MoO_3 . As_2O_5 . 3\ Ag_2O.$$

Debray obtained the acids and one or two salts of two different series, which may be represented respectively by the formulas: —

$$20\ MoO_3 . As_2O_5 . 3\ H_2O + 24\ aq$$
$$20\ MoO_3 . As_2O_5 . 3\ K_2O$$
$$20\ MoO_3 . As_2O_5 . 3\ (NH_4)_2O$$
$$6\ MoO_3 . As_2O_5 . 3\ H_2O + 13\ aq$$
$$6\ MoO_3 . As_2O_5 . 4\ (NH_4)_2O + aq$$
$$6\ MoO_3 . As_2O_5 . (NH_4)_2O + 4\ aq$$
$$6\ MoO_3 . As_2O_5 . Na_2O + 12\ aq.$$

Debray considers the formula of the 20-atom ammonium salt as probable only, and regards the water determination in the corresponding acid as not quite certain. Neither Seyberth nor Debray has described the analytical methods employed, or given the details of the analyses.

I have found it most advantageous to separate arsenic from molybdic oxide by precipitating with magnesia mixture, redissolving the ammonio-magnesic arsenate, and precipitating a second time with ammonia after adding a little magnesia mixture. The ammonio-magnesic arsenate may be digested with ammonic sulphide without decomposition; but after the second precipitation it does not retain molybdic oxide, and the subsequent treatment is therefore unnecessary. To determine the sum of the molybdic and arsenic oxides I precipitate the two together with mercurous nitrate and mercuric oxide, in the manner already described for the estimation of molybdic and phosphoric oxides, filter upon paper, and after drying roll up the filter and its contents and ignite cautiously in a porcelain crucible. By slow and careful heating the filter may be completely burned without loss of molybdic or arsenic oxides, this result being attained by the oxygen of the mercurous and mercuric oxides present. A weighed quantity of sodic tungstate is then to be added in fine powder, the mass well mixed in the crucible, and then cautiously heated until mercury is completely expelled, and after cooling a white fused mass remains. A second or even a third heating is necessary to insure a perfectly constant weight. The difference between the percentage of arsenic oxide, As_2O_5, and the sum of the percentages of the arsenic and molybdic oxides, gives the percentage of molybdic oxide with a very fair degree of approximation. In these salts the water must always be determined by ignition with sodic tungstate or some similar compound, since both arsenic and molybdic oxides are volatile.

Sixteen to one Series. — When solutions of ammonic arsenate and acid molybdate (7 : 3 salt) are mixed, a beautiful white crystalline precipitate is thrown down, which is very insoluble in cold water but dissolves slightly in boiling water, giving, however, a turbid solution. The salt is readily soluble in ammonia water. The portion analyzed was well washed on a filter with cold water and dried on woollen paper. In this salt, —

1.1322 gr. lost on ignition with WO_4Na_2 0.1636 gr. NH_3 and H_2O = 14.45%
1.3389 gr. gave 0.2481 gr. NH_4Cl = 9.00% $(NH_4)_2O$
1.4276 gr. " 0.1478 gr. $As_2O_7Mg_2$ = 7.68% As_2O_5

The analyses lead to the formula

$$16\,MoO_3 \,.\, As_2O_5 \,.\, 5\,(NH_4)_2O \,.\, H_2O + 8\text{ aq.}$$

which requires: —

		Calc'd.		Found.	
16 MoO_3	2304	77.94	85.72	77.97	85.65
As_2O_5	230	7.78		7.68	
5 $(NH_4)_2O$	260	8.79	14.28	9.00	14.45
9 H_2O	162	5.49		5.45	
	2956				

The salt may have lost a little ammonia in drying. When potassic arsenate and acid molybdate are mixed, a similar salt is formed. A solution of arsenic acid gives at once in solutions of acid ammonic or potassic molybdate a beautiful white crystalline precipitate, insoluble in cold water, but soluble in a large quantity of boiling water, forming cloudy solutions which pass freely through a filter. These may serve as starting-points for new investigations. The arsenio-molybdate above described is not perceptibly altered by long boiling with nitric acid, but the existence of higher compounds containing 22 or 24 molecules of molybdic to one of arsenic oxide appears at least extremely probable.

The phospho-molybdates and arsenio-molybdates now known with some degree of certainty are as follows: —

$24\,MoO_3 . P_2O_5 . 6\,H_2O + 47\,aq$	$Mo_{24}P_2O_{71}(HO)_{12} + 47\,aq$
$24\,MoO_3 . P_2O_5 . 6\,H_2O + 43\,aq$	$Mo_{24}P_2O_{71}(HO)_{12} + 43\,aq$
$24\,MoO_3 . P_2O_5 . 6\,H_2O + 24\,aq$	$Mo_{24}P_2O_{71}(HO)_{12} + 24\,aq$
$24\,MoO_3 . P_2O_5 . 2\,K_2O . 4\,H_2O$	$Mo_{24}P_2O_{71}(KO)_4(HO)_8$
$24\,MoO_3 . P_2O_5 . CeO . 5\,H_2O + 18\,aq$	$Mo_{24}P_2O_{71}(CeO_2)(HO)_{10} + 18\,aq$
$48\,MoO_3 . 2\,P_2O_5 . 5\,(NH_4)_2O . H_2O + 16\,aq$	$Mo_{48}P_4O_{148}(NH_4O)_{10}(HO)_2 + 16\,aq$

$22\,MoO_3 . P_2O_5 . 3\,(NH_4)_2O . 3\,H_2O + 9\,aq$	$Mo_{22}P_2O_{65}(NH_4O)_6(HO)_6 + 9\,aq$
$22\,MoO_3 . P_2O_5 . 3\,(NH_4)_2O . 3\,H_2O + 6\,aq$	$Mo_{22}P_2O_{65}(NH_4O)_6(HO)_6 + 6\,aq$
$22\,MoO_3 . P_2O_5 . 3\,(NH_4)_2O$	$Mo_{22}P_2O_{68}(NH_4O)_6$
$22\,MoO_3 . P_2O_5 . 3\,K_2O . 3\,H_2O + 9\,aq$	$Mo_{22}P_2O_{65}(KO)_6(HO)_6 + 9\,aq$
$22\,MoO_3 . P_2O_5 . 7\,Ag_2O + 14\,aq$	$Mo_{22}P_2O_{64}(AgO)_{14} + 14\,aq$
$44\,MoO_3 . 2\,P_2O_5 . 5\,K_2O . H_2O + 21\,aq$	$Mo_{44}P_4O_{136}(KO)_{10}(HO)_2 + 21\,aq$

$60\,MoO_3 . 3\,P_2O_5 . 8\,(NH_4)_2O . H_2O + 11\,aq$	$Mo_{60}P_6O_{186}(NH_4O)_{16}(HO)_2 + 11\,aq$

$18\,MoO_3 . P_2O_5 . Na_2O . 5\,H_2O + m\,aq$	$Mo_{18}P_2O_{53}(NaO)_2(HO)_{10} + m\,aq$
$18\,MoO_3 . P_2O_5 . 2\,Na_2O . 4\,H_2O + n\,aq$	$Mo_{18}P_2O_{53}(NaO)_4(HO)_8 + n\,aq$
$16\,MoO_3 . P_2O_5 . 3\,(NH_4)_2O . 3\,H_2O + 11\,aq$	$Mo_{16}P_2O_{47}(NH_4O)_6(HO)_6 + 11\,aq$

$5\,MoO_3 . P_2O_5 . 3\,Na_2O . 3\,H_2O + 11\,aq$	$Mo_5P_2O_{14}(NaO)_6(HO)_6 + 11\,aq$
$5\,MoO_3 . P_2O_5 . 3\,(NH_4)_2O . 3\,H_2O + 4\,aq$	$Mo_5P_2O_{14}(NH_4O)_6(HO)_6 + 4\,aq$
$5\,MoO_3 . P_2O_5 . 3\,K_2O . 3\,H_2O + 4\,aq$	$Mo_5P_2O_{14}(KO)_6(HO)_6 + 4\,aq$
$5\,MoO_3 . P_2O_5 . 3\,Ag_2O . 3\,H_2O + 4\,aq$	$Mo_5P_2O_{14}(AgO)_6(HO)_6 + 4\,aq$

$10\,MoO_3 . 2\,P_2O_5 . 5\,K_2O . H_2O + 19\,aq$	$Mo_{10}P_4O_{34}(KO)_{10}(HO)_2 + 19\,aq$
$10\,MoO_3 . 2\,P_2O_5 . 5\,(NH_4)_2O . H_2O + 6\,aq$	$Mo_{10}P_4O_{34}(NH_4O)_{10}(HO)_2 + 6\,aq$

$20\,MoO_3 . As_2O_5 . 6\,H_2O + 21\,aq$	$Mo_{20}As_2O_{59}(HO)_{12} + 21\,aq$
$20\,MoO_3 . As_2O_5 . 3\,K_2O$	$Mo_{20}As_2O_{62}(KO)_6$
$20\,MoO_3 . As_2O_5 . 3\,(NH_4)_2O$	$Mo_{20}As_2O_{62}(NH_4O)_6$

$16\,MoO_3 . As_2O_5 . 5\,(NH_4)_2O . H_2O + 8\,aq$	$Mo_{16}As_2O_{47}(NH_4O)_{10}(HO)_2 + 8\,aq$

$7\,MoO_3 . As_2O_5 . 6\,H_2O + 8\,aq$	$Mo_7As_2O_{20}(HO)_{12} + 8\,aq$
$7\,MoO_3 . As_2O_5 . (NH_4)_2O . 5\,H_2O$	$Mo_7As_2O_{20}(NH_4O)_2(HO)_{10}$
$7\,MoO_3 . As_2O_5 . 3\,BaO$	$Mo_7As_2O_{23}(BaO_2)_3$
$7\,MoO_3 . As_2O_5 . 3\,Ag_2O$	$Mo_7As_2O_{28}(AgO)_6$

$6\,MoO_3 . As_2O_5 . 6\,H_2O + 10\,aq$	$Mo_6As_2O_{17}(HO)_{12} + 10\,aq$
$6\,MoO_3 . As_2O_5 . 4\,(NH_4)_2O + aq$	$Mo_6As_2O_{19}(NH_4O)_8$
$6\,MoO_3 . As_2O_5 . (NH_4)_2O . 2\,H_2O + 2\,aq$	$Mo_6As_2O_{20}(NH_4O)_2(HO)_4 + 2\,aq$
$6\,MoO_3 . As_2O_5 . Na_2O . 5\,H_2O + 7\,aq$	$Mo_6As_2O_{17}(NaO)_2(HO)_{10} + 7\,aq$

For the convenience of comparison with the corresponding compounds of tungsten, I have in writing these formulas as far as possible assumed that all the phospho-molybdic and arsenio-molybdic acids contain 12 atoms of hydroxyl, or, in the language appropriate to the old notation, are six-basic. With the material before us, we are now prepared to discuss the question of the basicity of the phospho-tungstates and phospho-molybdates as well as of the corresponding arsenic compounds.

The general results to which the study of the phospho-molybdates and arsenio-molybdates has led are as follows: —

1. The phospho-molybdates form a series of which the lowest term contains five atoms of molybdic to one of phosphoric oxide, and the highest twenty-four atoms of the former to one of the latter.

2. As in the case of the phospho-tungstates, the greater number of the molybdenum compounds contain an even number of atoms of tungstic oxide. The homologizing term is therefore $2\ MoO_3$ for these cases.

3. By far the greater number of phospho-molybdates contain *three* atoms of fixed base (old style), or, in more modern language, may be considered as derived from acids containing *six* atoms of hydroxyl. Anhydrous compounds of this type occur, and are not always simply residues obtained by heating salts which may be considered as acid, as containing, for example, $3\ R_2O\ .\ 3\ H_2O$. It seems therefore necessary to admit the existence of acids of the general type

$$n\ MoO_3\ .\ P_2O_5\ .\ 3\ H_2O,$$

which may, however, stand in the relation of pyro-acids to other acids of the type

$$n\ MoO_3\ .\ P_2O_5\ .\ 6\ H_2O\ .$$

4. On the other hand, while no single phospho-molybdate containing more than three atoms of fixed base for one of phosphoric oxide has been obtained in a state of indubitable purity, it is probable that there is at least one salt with *six* or more atoms of fixed base. I refer to the silver salt which I have expressed by the formula

$$22\ MoO_3\ .\ P_2O_5\ .\ 7\ Ag_2O + 14\ aq.$$

5. Setting aside the evidence derived from the analogy of the phospho-molybdates and phospho-tungstates, there is at present no sufficient proof of the existence of a series of phospho-molybdates or arsenio-molybdates containing more than *three* atoms of fixed base. Such purely negative evidence must not be too highly regarded.

6. As in the case of the phospho-tungstates, there exists a class of phospho-molybdates in which the ratio of the number of atoms of base to that of the number of atoms of phosphoric oxide is as 5 : 2, the number of atoms of molybdic oxide being even.

Since the publication of my work on the phospho-tungstates and arsenio-tungstates a paper by Sprenger * on the phospho-tungstates has appeared. Sprenger has examined, with a single exception, only the compounds of the 24 : 1 series, and has added a number of new salts, which, so far as regards their constitution, fully confirm my own results. The compounds described, belonging to the 24-atom series, are the following: —

$$24\ WO_3 . P_2O_5 . 3\ H_2O + 58\ aq$$
$$24\ WO_3 . P_2O_5 . 3\ BaO + 58\ aq$$
$$24\ WO_3 . P_2O_5 . 2\ BaO . H_2O + 58\ aq$$
$$24\ WO_3 . P_2O_5 . BaO . 2\ H_2O + 58\ aq$$
$$24\ WO_3 . P_2O_5 . 3\ Cu_2O + 58\ aq$$
$$24\ WO_3 . P_2O_5 . 3\ Ag_2O + 58\ aq$$
$$24\ WO_3 . P_2O_5 . Ag_2O . H_2O + 58\ aq.$$

Sprenger's formula for the octahedral acid agrees with that which I had given if we consider the acid as tribasic. The other salts which he has described are new, and form a valuable addition to our knowledge of this class of compounds. It is well worthy of notice, that in all of his salts, the acid included, the number of atoms of water is the same. The acid with 58 atoms of water of crystallization forms, therefore, a complete and stable molecular structure in which 2, 4, or 6 atoms of hydrogen are replaceable. I do not recall any other series in which this constancy of crystalline water occurs, at least to the same extent. Sprenger has also obtained a salt of the 22-atom series which is of much interest. This is the barium salt

$$22\ WO_3 . P_2O_5 . 7\ BaO + 59\tfrac{1}{2}\ aq,$$

and its special interest depends upon the fact, first, that the ratio of the tungstic to the phosphoric oxide is as 22 : 1, and, secondly, that the salt contains *seven* atoms of fixed base, or, in other words, must be considered as derived from an acid containing at least *fourteen* atoms of hydroxyl. Sprenger asserts that he has obtained the corresponding acid, and it is to be hoped that he will pursue the subject farther. This barium compound furnishes additional evidence of the independent existence of a series in which the ratio is 22 : 1, and in addition it renders more probable the formula which I have given for Debray's silver salt,

$$22\ MoO_3 . P_2O_5 . 7\ Ag_2O + 14\ aq.$$

From these two tolerably well-established cases it would appear that

* Journal für prakt. Chemie, xxii. 418.

we are not justified in holding that the phospho-tungstates, phospho-molybdates, and corresponding arsenic compounds, have a basicity of which the higher limit is six. I may here mention that I shall hereafter describe a vanadio-molybdate of ammonium the analyses of which agree well with the formula

$$18\ MoO_3 \cdot V_2O_5 \cdot 8\ (NH_4)_2O + 15\ aq.$$

The risk of drawing hasty conclusions from purely negative evidence is particularly great in discussing the degree of basicity of this whole class of compounds, but I shall endeavor to show that it is possible to devise structural formulas which will embrace and explain all degrees of basicity which appear to be possible under the general conditions of the problem.

We may, as in the case of the alkaline tungstates already discussed, assume that both tungsten and molybdenum are hexatomic, and, as in that case, we may start from the commonly received formula for potassic dichromate,

$$\begin{array}{l} CrO_2 - O - K \\ \quad | \\ \quad O \\ \quad | \\ CrO_2 - O - K \end{array}$$

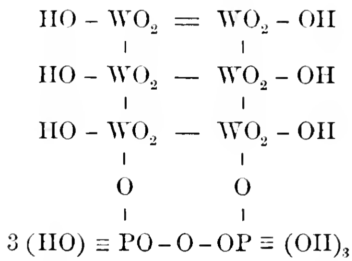
which may be equally well applied to hexatomic tungsten,

$$\begin{array}{c} O \\ \| \\ O = W - O - K \\ | \\ O \\ | \\ O = W - O - K \\ \| \\ O \end{array}$$

If we further suppose that the separate terms of the structural formulas are symmetrically arranged, and take a 6 : 1 phospho-tungstate

$$6\ WO_3 \cdot P_2O_5 \cdot 6\ H_2O \qquad \text{or} \qquad 6\ WO_2 \cdot P_2O_5 \cdot (HO)_{12}$$

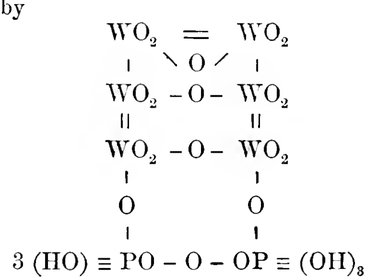
as an illustration, we may, with at least a certain degree of probability, express the structure as follows : —



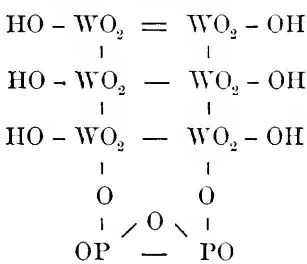
This formula explains the basicity of the acid satisfactorily. It also shows that, as six atoms of hydroxyl are united with phosphorus, and six with tungstic oxide, there should be theoretically a limiting case corresponding to an acid containing six atoms of hydroxyl, and represented by the formula

$$6\ WO_3 . P_2O_5 . 3\ H_2O \quad \text{or} \quad 6\ WO_2 . O_3 . P_2O_5 . (HO)_6$$

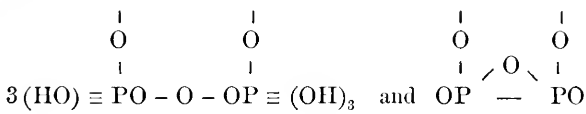
and structurally by



According to this view six atoms of hydroxyl are always associated with phosphorus, or, as the case may be, with arsenic. I consider this view of the subject by far the more probable. At the same time, however, it is also possible that we may have the structural formula,



in which all the atoms of hydroxyl are associated directly with tungsten, and in the present state of our knowledge we can only decide the question upon general grounds of probability, so that our conclusions are at best uncertain. Finally, both formulas being at least possible, it may be that there are two isomeric modifications of each series of acids represented respectively by the formulas above given. There is no present evidence of the existence of such isomeric modifications in the case of phospho-tungstates, phospho-molybdates, or the corresponding arsenic series; but Marignac has shown that there are two isomeric series of silico-tungstates, which he calls respectively silico-tungstates and tungsto-silicates, and it may be that the difference between these depends upon differences in the mode of combination, precisely similar to those which I have pointed out above. I shall return to this subject in the general discussion of my results. With respect to the two linking terms,

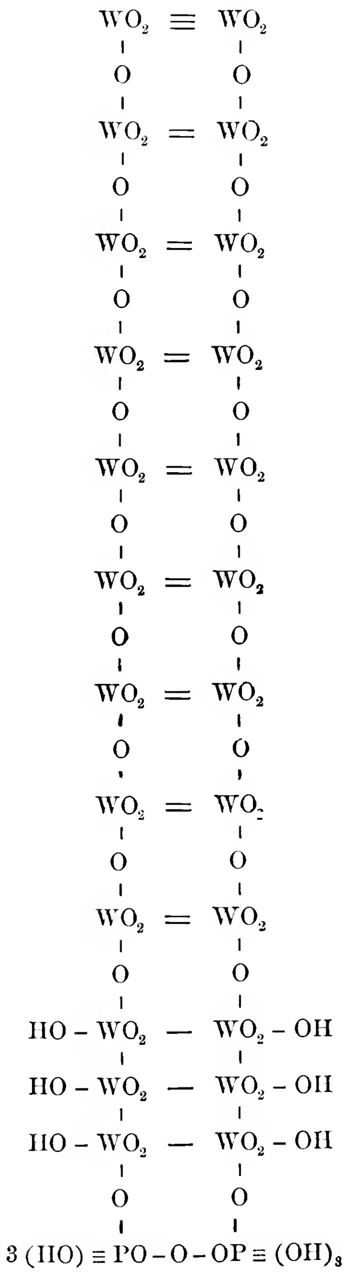


no assumption is made which is not in perfect accordance with commonly accepted views of the subject.

We may now consider the most general case, that, namely, in which there are twenty-four atoms of tungstic or molybdic, to one of phosphoric or arsenic oxide. We have for an acid of this type

$$24\ WO_3 \cdot P_2O_5 \cdot 6\ H_2O \qquad \text{or} \qquad 24\ WO_2 \cdot O_{18} \cdot P_2O_5 \cdot (HO)_{12}$$

and in accordance with the principles above laid down the structural formula may be written:—



The case of an acid containing for twenty-four atoms of tungstic oxide six atoms of hydroxyl may easily be deduced from the above, upon the principle explained in the first example cited. Without again writing the cumbrous formula, it may easily be seen that the cases of acids containing more than twelve atoms of hydroxyl, if such really exist, are embraced in the above-given structural formula, and that in such cases there will be two variations in the mode of combination of the hydroxyl, similar to the two which occur when there are six or twelve atoms of hydroxyl. The structural formula given would explain simply and naturally the *tribasic* character of all known phospho-molybdates and phospho-tungstates containing twenty-four atoms of metallic oxide, since in these all the hydroxyl may be united with phosphorus exclusively, or with tungsten exclusively. It only remains to consider the case of the compounds having for one atom of phosphoric or arsenic oxide an *uneven* number of atoms of metallic oxide, as, for instance, the 5 : 1 and 7 : 1 series. In these cases also there exists, as has been shown, a second and derived series, of which the successive terms are to be regarded as formed from those of the first series by doubling the molecular weight and dropping an atom of fixed base. Thus, we have

$5\,MoO_3 . P_2O_5 . 3\,H_2O$	and	$10\,MoO_3 . 2\,P_2O_5 . 5\,K_2O . H_2O + 19\,aq$
$7\,MoO_3 . As_2O_5 . 3\,H_2O$		$14\,WO_3 . 2\,P_2O_5 . 5\,Na_2O . H_2O + 42\,aq$
$22\,MoO_3 . P_2O_5 . 3\,H_2O$		$44\,MoO_3 . 2\,P_2O_5 . 5\,K_2O . H_2O + 21\,aq$
$24\,MoO_3 . P_2O_5 . 3\,H_2O$		$48\,MoO_3 . 2\,P_2O_5 . 5(NH_4)_2O . H_2O + 16\,aq$

All these salts appear to have an acid reaction. They may all be regarded as acid six-basic salts, and it is easy to see that the two series may be reduced to one by doubling the formulas of all the terms on the left, so that we shall have a single series, of which the successive terms are

$$10\,MoO_3 . 2\,P_2O_5 . 6\,H_2O$$
$$12\,MoO_3 . 2\,As_2O_5 . 6\,H_2O$$
$$14\,WO_3 . 2\,P_2O_5 . 6\,H_2O$$
. . . .
$$48\,MoO_3 . 2\,P_2O_5 . 6\,H_2O$$

This view in no wise excludes acids or salts of a higher degree of basicity. It has the advantage of bringing all the compounds together, and of being more completely in accordance with what we know of the constitution of salts belonging to simpler types. The structural formulas which I have given — provisionally, of course —

may easily be modified to suit this view, and will all be symmetrical, and suggestive of various possible isomerisms.

The study of other complex inorganic acids will, doubtless, throw further light upon the subject, and to it I shall continue to devote my leisure. It already begins to appear that inorganic compounds may possess an unexpected degree of complexity, and that very wide fields of research in inorganic chemistry are still open.

(*To be continued.*)

VII.

AN INDIRECT DETERMINATION OF CHLORINE AND BROMINE BY ELECTROLYSIS.

By Leonard P. Kinnicutt.

Presented November 9th, 1881.

In the indirect determination of chlorine and bromine the method most commonly employed is to precipitate both halogens with argentic nitrate, and then either to reduce the weighed argentic chloride and bromide to metallic silver by heating in an atmosphere of hydrogen, or to change the bromide into chloride by heating in a stream of chlorine gas.

The determination by either method is difficult, requires the closest attention, and is liable to give erroneous results; both on account of the slight loss that may occur in transferring the weighed chloride and bromide from the crucible to the glass tube, and also from slight volatilization during the heating. I have found that even in reducing the mixed haloids to metallic silver in a slow current of hydrogen, small particles of silver are almost always carried by the gas along the tube. Led by these facts, I attempted during the past winter to find a new method which would, if possible, from its accuracy and simplicity, tend to bring the indirect determination of chlorine and bromine when they occur in organic compounds more into vogue than is at present the case. In this attempt I believe I have been successful, and the method I have devised is based on the principle that melted argentic chloride and bromide are easily reduced to metallic silver by the galvanic current.

The details of the process are as follows: —

After the mixture of the two halogen compounds of silver has been heated in a porcelain crucible so that they just fuse together, the crucible is cooled and weighed, a piece of platinum foil connected with a platinum wire is placed in the crucible so that it rests on the melted silver salts, and dilute sulphuric acid (1 pt. conc. to 3 pts. water by volume) is poured into the crucible until it is two-thirds full, a second piece of platinum foil united to a wire is then placed in the acid solution, care being taken that it does not touch the silver mixture. The zinc pole of a two-cell Bunsen battery is connected with the platinum foil that rests on the silver salts, and the carbon pole with the platinum foil just mentioned. The decomposition begins immediately, chlorine and bromine being given off from the positive electrode, the reduced silver remaining at the bottom of the crucible in the form of a porous mass. The reaction requires from twelve to eighteen hours; with a weight of less than one and a half grammes of the mixed haloids I have found twelve hours sufficient to produce complete reduction; with a weight exceeding that amount I prefer to allow eighteen. When the argentic chloride and bromide are completely reduced, the battery is disconnected, the electrodes taken out of the sulphuric acid solution and washed with distilled water. The sulphuric is then poured off from the silver, and the silver is washed by decantation with distilled water, the decanted liquid being poured through a small filter; this is afterwards burnt, added to the silver sponge which still remains in the crucible; the crucible is then heated over a low free flame to constant weight. The weight thus found, minus the weight of the crucible and filter ash, is of course the weight of silver contained in the argentic chloride and bromide.

The only point that requires any great degree of care in this process is the melting of the mixed haloids. The temperature at which the fusion takes place must be as low as possible, so as to avoid any volatilization, and the melted mass should be united as far as practicable in one piece.

In some of the following analyses I have used a platinum crucible. When this has been the case, one wire has been wound around the crucible, while the other, as before, has been merely allowed to dip into the acid solution; in this way the whole crucible serves as an electrode, and there is no need of bringing the melted chloride and bromide into one globule. With a platinum crucible, the washing of the reduced silver must be continued until a few drops of the filtrate gives no precipitate with baric chloride, and the drying should be done in an air bath at a temperature of about 150° C. After weighing, the silver, which always adheres to the crucible, can be dissolved out with dilute nitric acid.

The first series of analyses shows the accuracy of the process when either argentic chloride or bromide is taken alone, the second series when they occur together.

First series of analyses.

Wt. taken. Argentic chloride.	Wt. found. Silver.	Wt. calculated. Silver.
0.7206 grammes.	0.5419 grammes.	0.5425 grammes.
1.2984 "	0.9771 "	0.9777 "
1.8455 "	1.3892 "	1.3889 "

Wt. taken. Argentic bromide.	Wt. found. Silver.	Wt. calculated. Silver.
0.9313 grammes.	0.5352 grammes.	0.5350 grammes.
0.9421 "	0.5424 "	0.5424 "

In this connection I publish, by permission, three analyses, made according to this process, by Prof. J. P. Cooke, in determining the purity of a sample of argentic bromide.

	Wt. of argentic bromide.	Wt. of silver.	Per cent of silver.
1.	4.1450 grammes.	2.3817 grammes.	57.444
2.	1.8172 "	1.0437 "	57.434
3.	4.9601 "	2.8497 "	57.449
		Mean value	57.442

Second series of analyses.

Wt. taken. Argentic bromide	Wt. taken. Argentic chloride.	Wt. found. Silver.	Wt. calculated. Silver.
0.9389 gr.	1.0498 gr.	1.3283 gr.	1.3293 gr.
1.0915 "	1.3042 "	1.6095 "	1.6086 "
1.1779 "	1.2551 "	1.6229 "	1.6217 "
1.2470 "	1.5420 "	1.8778 "	1.8770 "
1.6153 "	0.6661 "	0.8560 "	0.8550 "

The slight increase of variation between the found and calculated results in this second series of analyses I attribute to a slight volatilization of the argentic chloride before the chloride undergoes fusion.

With the argentic iodide I have only tried qualitative experiments, but I can see no reason why its determination when mixed with either argentic chloride or bromide cannot be accomplished according to this method.

VIII.

CONTRIBUTIONS FROM THE CHEMICAL LABORATORY OF HARVARD COLLEGE.

By Charles F. Mabery.

Presented February 8, 1882.

The investigations described in the following papers were made under my supervision, and they formed a part of the work in the Summer Course of Instruction in Chemistry for 1881.

DIBROMIODACRYLIC AND CHLORBROMIODACRYLIC ACIDS.

Charles F. Mabery and Rachel Lloyd.

From the ease with which various substituted acrylic acids have been obtained from brompropiolic acid,* we were led to believe that derivatives of some interest would result by the simultaneous addition of different halogens. This idea was confirmed by a few preliminary experiments, which showed that iodine monobromide and iodine monochloride could readily be made to form addition-products with brompropiolic acid. These substances have been submitted to a careful study, and the results we have obtained are presented in this paper.

Dibromiodacrylic Acid.

Dibromiodacrylic acid was made from brompropiolic acid, by the action of iodine monobromide. In the preparation of iodine monobromide according to the method of Lagermarck,† the required weight of iodine, with an excess of bromine, was heated to 50° for ten minutes

* These Proceedings, Vol. XVI. pp. 211, 235.
† Berichte der deutsch. chem. Gesellsch. 1874, 907.

on the water bath. Dibromiodacrylic acid was formed in small quantity, when the solid residue left by evaporation of the excess of bromine was dissolved in ether and allowed to stand with brompropiolic acid. The product of this reaction, however, consisted to a large extent of an oil, from which very little pure substance could be recovered. This difficulty was partially overcome by the application of heat; and by boiling the solution for an hour on the water bath we succeeded in obtaining about forty per cent of the amount theoretically required. The thick pasty mass left after the evaporation of the ether soon solidified, and was easily purified by crystallization from hot water.

Dibromiodacrylic acid dissolves readily in ether, alcohol, carbonic disulphide, and chloroform. In cold water it is rather sparingly soluble; from a concentrated hot solution it falls at first as an oil, which crystallizes as the solution cools, in oblique prisms of the monoclinic system. It melts at 139°–140°, and sublimes slowly at higher temperatures.

The composition of this substance was determined by the following analyses: —

I. 1.0762 grm. of the substance gave 0.3385 grm. CO_2 and 0.0420 grm. H_2O.

II. 0.1993 grm. of the substance gave by the method of Carius 0.3385 grm. Ag Br + Ag I.

	Calculated for $C_3HBr_2IO_2$.	Found. I.	Found. II.
C	10.11	9.85	
H	.28	.43	
2 Br + I	80.63		80.21

To determine the solubility of this acid at ordinary temperatures, we used the method of V. Meyer. The filtered solution was neutralized with baric carbonate, and the barium estimated by precipitation with sulphuric acid.

I. 8.7164 grms. solution gave 0.0968 grm. $BaSO_4$.

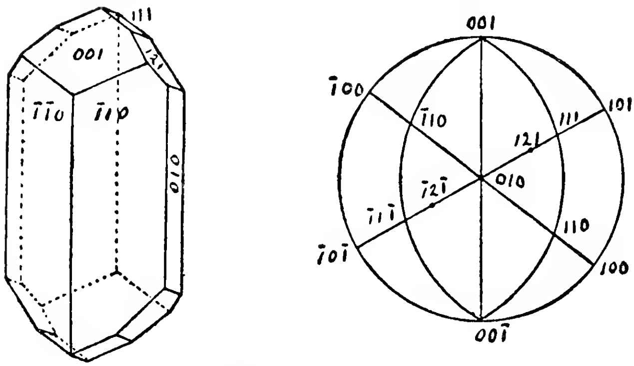
II. 9.7772 grms. solution gave 0.1089 grm. $BaSO_4$.

The solution saturated at 20° contains, therefore, the percentages: —

I.	II.
3.39	3.40

Dr. W. H. Melville has made a crystallographic examination of this substance, and obtained the following results: —

CRYSTALLINE FORM OF DIBROMIODACRYLIC ACID.



MONOCLINIC SYSTEM.

Forms {001}, {010}, {110}, {121}, {111}.*

Elements: — Clinodiagonal, $a = 0.617$
Orthodiagonal, $b = 1.$
Vertical Axis, $c = 0.581$
Angle of Axes $= 52° 11\frac{1}{2}'$

				Observed.	Calculated.
Angles between normals	001	and	110	123° 26′	Fundamental angles
	110	"	010	64°	Fundamental angles
	111	"	110	59° 14′½	Fundamental angles
	111	"	010	62° 11′	61° 47′
	121	"	010	42° 59′	42° 58′
	121	"	001	70° 29′	70° 19′
	121	"	110	55° 59′	56° 13′
	121	"	$\bar{1}$10	84° 55′	85° 5′½

The following salts of this acid have been examined: —

Baric dibromiodacrylate $Ba(C_3Br_2IO_2)_2 . 3\frac{1}{2}H_2O$.

To prepare the barium salt, a solution of the acid was neutralized with baric carbonate and the filtered solution concentrated by evaporation. On cooling the salt crystallized in rhombic prisms, which were

* The form {111} appeared only on a few crystals.

very soluble in hot, less soluble in cold water. The air-dried salt lost three and a half molecules of crystal water at 80°.

I. 0.7087 grm. of the air-dried salt lost 0.0512 grm. H_2O at 80°.
II. 0.7273 grm. of the salt lost 0.0535 grm. H_2O at 80°.
III. 0.6241 grm. of the salt lost 0.0441 grm. H_2O at 80°.
IV. 0.6575 grm. of the anhydrous salt gave 0.1808 grm. Ba SO_4.

	Calculated for $Ba(C_3Br_2IO_2)_2 . 3\frac{1}{2}H_2O$.	Found. I.	II.	III.
H_2O	6.92	7.23	7.36	7.06

	Calculated for $Ba(C_3Br_2IO_2)_2$.	Found.
Ba	16.17	16.16

The solubility of this salt in cold water was determined by V. Meyer's method. The saturated solution was filtered, evaporated to dryness, and the barium estimated by ignition with sulphuric acid.

I. 2.6342 grms. of a solution saturated at 20° gave 0.1038 grm. $BaSO_4$.
II. 2.0175 grms. of a solution saturated at 20° gave 0.0806 grm. $BaSO_4$.

From these determinations the following percentages were calculated: —

I.	II.
14.32	14.52

Calcic dibromiodacrylate $Ca(C_3Br_2IO_2)_2$.

The calcium salt was made by saturating an aqueous solution of the acid with calcic carbonate. From the concentrated solution the salt crystallized in clustered needles which were less soluble in cold than in hot water. When air-dried it was constant at 80°.

0.4118 grm. of the salt dried at 80° gave 0.0714 grm. $CaSO_4$.

	Calculated for $Ca(C_3Br_2IO_2)_2$.	Found.
Ca	5.33	5.10

Potassic dibromiodacrylate $KC_3Br_2IO_2$?

This salt was prepared by neutralizing an aqueous solution of the acid with potassic carbonate and evaporating on the water bath. It separated in the form of rhombic plates, which proved to be so deliquescent that we were unable to determine the water of crystallization.

0.8834 grm. of the salt dried at 80° gave 0.1842 grm. K_2SO_4.

	Calculated for $KC_3Br_2IO_2$.	Found.
K	9.92	9.92

Argentic dibromiodacrylate $AgC_3Br_2IO_2$.

From a hot aqueous solution of the acid the silver salt is precipitated by the addition of argentic nitrate in hexagonal plates. It may be recrystallized from hot water without decomposition, and it is but slightly affected by the action of light. The salt was dried over sulphuric acid for analysis.

1.0737 grm. of the salt gave by precipitation with HBr 0.4288 grm. AgBr.

	Calculated for $AgC_3Br_2IO_2$.	Found.
Ag	23.32	22.98

When dibromiodacrylic acid is heated to 100° in a closed tube with bromine, iodine is set free and bromine takes its place. The substance thus formed is identical with the tribromacrylic acid described by Professor H. B. Hill and one of us* as shown by its melting point 115–118°, and by a study of its crystalline form. The following angles were measured by Dr. Melville:—

	Angles between normals.	Tribromacrylic acid from dibromiodacrylic.	Tribromacrylic acid from brompropiolic.
Zone [010, 110]	110 and 010	65° 33′	65° 38′
	010 " $\bar{1}10$	65° 44	
	$\bar{1}10$ " $\bar{1}\bar{1}0$	48° 28′	48° 40′
	$\bar{1}\bar{1}0$ " $0\bar{1}0$	65° 52½′	
	$0\bar{1}0$ " $1\bar{1}0$	65° 35′	
	$1\bar{1}0$ " 110	48° 44′	
		359° 56½′	
Zone [010, 011]	010 and 011	63° 11′	63° 14′
	011 " $0\bar{1}1$	54° 5′	53° 33′
	$0\bar{1}1$ " $0\bar{1}0$	62° 56′	

* These Proceedings, Vol. XVI. p. 216.

It also gave the percentage of bromine required for tribromacrylic acid.

0.1553 grm. substance gave 0.2819 grm. AgBr.

	Calculated for $C_3HBr_3O_2$.	Found.
Br	77.66	77.25

Chlorbromiodacrylic Acid.

Chlorbromiodacrylic acid may be prepared most conveniently by heating brompropiolic acid with an ethereal solution of iodine monochloride, although without the application of heat the reaction takes place slowly. Iodine monochloride was made according to the method proposed by Bunsen.* The calculated weight of iodine was dissolved in aqua regia with the aid of heat, and after cooling the solution was extracted with ether and washed thoroughly with water. When brompropiolic acid is heated for an hour with this solution, the oily liquid left on evaporation of the ether soon deposits large prismatic crystals of the addition-product. For purification the crude product was pressed in filter paper and recrystallized from hot water.

This substance is readily soluble in ether and alcohol, somewhat less so in carbonic disulphide and chloroform. From a hot aqueous solution it separates as an oil which crystallizes on cooling in rhombic prisms of the monoclinic system. By crystallization from water we did not succeed in raising the melting point above 110°; but the crystals formed by slow evaporation of a solution in carbonic disulphide melted at 115–116°. It sublimes freely at somewhat higher temperatures.

This acid was identified by the following analyses: —

I. 0.6743 grm. substance gave 0.2843 grm. CO_2.†

II. 0.1505 grm. substance gave 0.2721 grm. AgCl + AgBr + AgI.

	Calculated for $C_3HClBrIO_2$.	Found. I.	Found. II.
C	11.55	11.50	
H	.32		
Cl + Br + I	77.84		77.41

* Ann. Chem. u. Pharm. LXXIV. 8.

† By an accident the water in this combustion was lost.

The following results were obtained in determining the solubility in cold water: —

I. 8.1470 grms. of a solution saturated at 20° gave 0.1396 grm. $BaSO_4$.

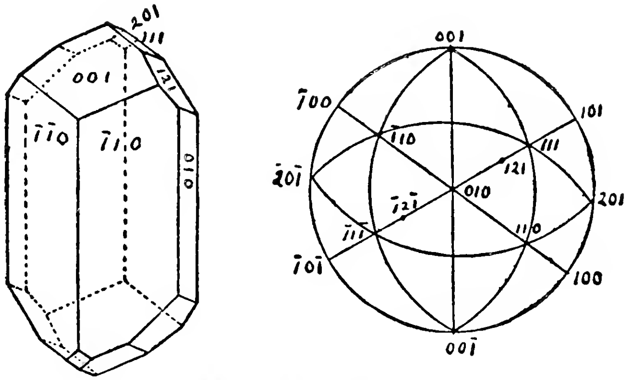
II. 5.4630 grms. of a solution saturated at 20° gave 0.0968 grm. $BaSO_4$.

From these results were calculated the percentages: —

I.	II.
4.58	4.74

For a determination of the crystalline form of this acid we are indebted to the kindness of Dr. Melville, who obtained the following results: —

CRYSTALLINE FORM OF CHLORBROMIODACRYLIC ACID.



MONOCLINIC SYSTEM.

Forms {001}, {010}, {110}, {121}, {111}, {201},

Elements: — Clinodiagonal, $a = 0.594$
Orthodiagonal, $b = 1.$
Vertical Axis, $c = 0.572$

Angle of axes XZ = 52° 47′

				Observed.	Calculated.
Angles between normals	111	and	110	58° 23′	Fundamental Angles.
	121	"	110	55° 45′	
	121	"	010	43° 48′	
	111	"	010	62° 43′	62° 28′
	110	"	001	123° 26′	123° 13′
	110	"	010	65° 3′	64° 56′
	111	"	$1\bar{1}0$	82° 24′	82° 23′

It will be seen by inspection of the forms of dibromiodacrylic and chlorbromiodacrylic acids that these substances present a striking instance of isomorphism. In fact the only form not common to both is that of {201}, which was not observed on the crystals of dibromiodacrylic acid. This similarity in form, which extends also to tribromacrylic acid, is rendered more prominent by a comparison of the observed angles. The measurements of tribromacrylic acid show a greater variation in the observed angles except in the case of the angle which the prism {110} makes with the pinacoid {010}.

	Dibromiod-acrylic acid.	Chlorbromiod-acrylic acid.	Tribrom-acrylic acid.
110 and 010	64°	65° 3′	65°33
110 " $\bar{1}10$	128°	130° 6′	
110 " 001	123° 26′	123° 26′	
111 " 010	62° 11′	62° 43′	
111 " 110	59° 14½′	58° 23′	
121 " 010	42° 59′	43° 48′	
121 " 110	55° 59′	55° 45′	

The elements of the crystals also proved to be nearly identical.

	Dibromiod-acrylic acid.	Chlorbromiod-acrylic acid.
Clinodiagonal a	0.617	0.594
Orthodiagonal b	1.	1.
Vertical axis c	0.581	0.572
Angle of axes XZ	52° 11′½	52° 47′

A study was made of some of the more important salts of chlorbromiodacrylic acid.

Baric chlorbromiodacrylate $Ba(C_3ClBrIO_2)_2 \cdot 3\frac{1}{2}H_2O$.

A solution of the acid was saturated with baric carbonate, filtered, and concentrated on the water bath. The salt separated on cooling in rectangular prisms, which when dried by exposure to the air contained three and a half molecules of crystal water. It is quite soluble in cold, and very soluble in hot water.

I. 0.8250 grm. of the air-dried salt lost when heated to 80° 0.0636 grm. H_2O.
II. 0.7273 grm. of the air-dried salt lost at 80° 0.0540 grm. H_2O.
III. 0.5401 grm. of the air-dried salt lost at 80° 0.0384 grm. H_2O.
IV. 0.5502 grm. of the air-dried salt lost at 80° 0.0438 grm. H_2O.

V. 0.6697 grm. of the anhydrous salt gave on ignition with H_2SO_4 0.2080 grm. $BaSO_4$.
VI. 0.5032 grm. of the anhydrous salt gave 0.1570 grm. $BaSO_4$.
VII. 0.4959 grm. of the anhydrous salt gave 0.1527 grm. $BaSO_4$.

	Calculated for $Ba(C_3ClBrIO_2)_2 . 3\frac{1}{2}H_2O$.	Found.			
		I.	II.	III.	IV.
H_2O	7.67	7.71	7.44	7.11	7.96

	Calculated for $Ba(C_3ClBrIO_2)_2$	Found.		
		V.	VI.	VII.
Ba	18.07	18.26	18.34	18.10

The solubility at 20° was determined by evaporating a saturated solution to dryness and igniting the residue with sulphuric acid.

I. 3.7500 grms. solution gave 0.2339 grm. $BaSO_4$.
II. 3.1458 grms. solution gave 0.1957 grm. $BaSO_4$.

According to these determinations a solution saturated at 20° contains the percentages: —

I.	II.
20.30	20.23

Calcic chlorbromiodacrylate $Ca(C_3ClBrIO_2)_2 . H_2O$.

When a solution of the acid is neutralized with calcic carbonate, and the filtered solution concentrated by evaporation, the calcium salt separates in the form of branching needles. The air-dried salt contains one molecule of crystal water, which it loses at 80°.

I. 0.7180 grm. of the air-dried salt lost 0.0216 grm. H_2O at 80°.
II. 0.6770 grm. of the air-dried salt lost 0.0197 grm. H_2O at 80°.
III. 0.6583 grm. of the anhydrous salt gave 0.1404 grm. $CaSO_4$.

	Calculated for $Ca(C_3ClBrIO_2)_2 . H_2O$.	Found.	
		I.	II.
H_2O	2.66	3.01	291

	Calculated for $Ca(C_3ClBrIO_2)_2$.	Found.
		III.
Ca	6.05	6.27

Potassic chlorbromiodacrylate $KC_3ClBrIO_2$?

The potassium salt is obtained as a very deliquescent solid mass by evaporating a solution of the acid after neutralizing with potassic carbonate.

0.8076 grm. of the salt dried at 80° gave on ignition with H_2SO_4 0.2176 grm. K_2SO_4.

	Calculated for $KC_3ClBrIO_2$.	Found.
K	11.19	11.27

Argentic chlorbromiodacrylate $AgC_3ClBrIO_2$.

The silver salt was prepared by the addition of argentic nitrate to a hot aqueous solution of the acid. It crystallizes in rhombic prisms, which are quite soluble in hot, sparingly soluble in cold water.

I. 0.5383 grm. of the salt gave 0.1825 grm. AgCl.
II. 0.5129 grm. of the salt gave 0.1766 grm. AgCl.

	Calculated for $AgC_3ClBrIO_2$.	Found.	
		I.	II.
Ag	25.80	25.52	25.91

PRELIMINARY NOTICE ON ORTHOIODBENZYLBROMIDE AND ITS DERIVATIVES.*

CHARLES F. MABERY AND FRANKLIN C. ROBINSON.

Orthoiodbenzylbromide is formed when bromine is allowed to act on orthoiodtoluol at temperatures near its boiling point. In the preparation of orthoiodtoluol we obtained the most satisfactory results from the sulphate of orthodiazotoluol. Orthotoluidin from the factory of Kahlbaum at Berlin was treated in quantities of 10 grms. each with two molecules of sulphuric acid, and to this mixture, kept cold with snow, was added gradually a solution of one molecule of sodic nitrite. On the addition of hydriodic acid (boiling point 127°) in slight excess over the calculated amount for the solution of the diazo-compound thus obtained, orthoiodtoluol was precipated as a heavy oily liquid.

* Since Professor Jackson decided not to include orthoiodbenzylbromide in his researches on the substituted benzyl compounds, we have undertaken its study. (C. F. M.)

The crude product was washed with sodic hydrate and acetic acid, and lastly with water. It was then dried over calcic chloride, and finally purified by fractional distillation. In this way from 20 grms. orthotoluidin we obtained before fractioning 28 grms. orthoiodtoluol, which gave 20 grms. boiling at 211° (mercury column wholly in vapor).*

To convert orthoiodtoluol into orthoiodbenzylbromide, 10 grms. were heated to 190–200° under a return condenser, and 10 grms. bromine allowed to run into the flask from a drop funnel as rapidly as it was absorbed. On cooling, the product of the reaction formed a thick oily liquid which did not solidify at 0°. It was therefore washed with a dilute solution of sodic hydrate, to remove the iodine which was invariably set free during the bromiring, and distilled in the vapor of concentrated hydrobromic acid according to the method followed by Professor Jackson in the purification of orthobrombenzylbromide.† The distillate solidified when cooled with snow, and after removing the oil by pressure in filter paper, it was purified by crystallization from ligroin.

The composition of this substance was established by the following analyses: —

I. 0.1994 grm. of the substance gave 0.3945 grm. Ag Br + Ag I.
II. 0.2793 grm. of the substance gave 0.3945 grm. Ag Br + Ag I.
III. 0.3246 grm. of the substance gave 0.3350 grm. CO_2 and 0.0674 grm. H_2O.

Calculated for C_7H_6BrI.		Found.		
		I.	II.	III.
C	28.28			28.16
H	2.02			2.30
Br + I	69.68	69.53	69.11	

Orthoiodbenzylbromide is readily soluble in ether, hot alcohol, benzol, carbonic disulphide, and chloroform. It is nearly, if not quite, insoluble in water, and very sparingly soluble in cold ligroin. From a cold saturated solution in ligroin it crystallizes in flattened prisms often 2 or 3 centimeters in length. When crystallization takes place from a hot solution it appears in the form of short thick prisms. The vapor of this substance affects the mucous membrane in the same way as that

* Kekulé, Berichte der deutsch. chem. Gesellsch. 1874, 1007.
† These Proceedings, Vol. XII. p. 217.

of all the benzyl compounds thus far examined, and it seems to be far more volatile than the corresponding para compound. It melts at 52–53°, and at higher temperatures sublimes slowly in oily drops which soon solidify in radiating needles. By oxidation with dilute nitric acid it is converted into an acid which melts at 150–155°. Since the orthoiodbenzoic acid obtained by Kekulé * from orthoiodtoluol melted at 155–156°, our product without doubt has the same composition.

As a further proof of the constitution of orthoiodbenzylbromide we made the nitril, and from it orthoiodalphatoluic acid. To form the nitril the bromide was boiled with an alcoholic solution of potassic cyanide. The oily liquid precipitated by the addition of water was heated to 125° for four hours with fuming hydrochloric acid. When cold the oil solidified, and more of the acid separated from the solution in long needles. After removing the excess of hydrochloric acid, the crude product was purified by crystallization from hot water.

Orthoiodalphatoluic acid crystallizes in fine felted needles which are sparingly soluble in cold, readily soluble in hot water and in alcohol, ether, carbonic disulphide, and ligroin. With the limited amount of material at our disposal we were unable to raise the melting point above 95–96°. It would seem, however, from the analogy of the orthobromalphatoluic acid that the melting point of our acid should be somewhat higher. When we return to this subject and have access to a larger supply of the acid, its melting point will be more carefully tested. The silver salt of this acid was made by adding argentic nitrate to an aqueous solution of the ammonium salt. It separated from the solution as a curdy precipitate which was but slightly soluble in water, readily soluble in dilute nitric acid. For analysis it was dried over sulphuric acid.

0.2615 grm. of the salt gave by precipitation with HCl 0.1008 grm. AgCl.

	Calculated for $C_7H_6ICOOAg$.	Found.
Ag	29.27	29.00

We also submitted the bromide to the action of alcholholic ammonia; but as the result of one experiment with a small quantity of substance we succeeded in isolating only the primary amine. The product of this reaction was treated with water, and the aqueous solution evaporated on the water bath. Upon the addition of sodic hydrate the free base

* Berichte der deutsch. chem. Gesellsch. 1874, 1007.

was partially precipitated as an oily liquid, and more of the oil was obtained by extracting the solution with ether. The residue left by evaporation of the ether was immediately converted into the carbonate by absorbing carbonic dioxide from the air. It was dissolved in alcohol, a little hydrochloric acid added, and the platinum salt formed by the addition of chlorplatinic acid. This salt crystallized in pale yellow microscopic prisms, which were sparingly soluble in water and cold alcohol, readily in hot, and insoluble in ether. It was purified by recrystallization from hot alcohol, washed with ether, and dried over sulphuric acid for analysis.

0.2082 grm. of the salt gave on ignition 0.0468 grm. platinum.

	Calculated for $(C_7H_6INH_3)_2PtCl_6$.	Found.
Pt	22.48	22.48

Since our work was interrupted by the closing of the summer term, a more complete examination of the derivatives of orthoiodbenzylbromide must be reserved for another paper.

CHLORTRIBROMPROPIONIC ACID.

Charles F. Mabery and H. C. Weber.

The formation of chlortribrompropionic acid by the action of bromine on chlorbromacrylic acid has been mentioned in a previous paper by R. Lloyd and one of us.* Although this reaction took place without difficulty in a chloroform solution at ordinary temperatures, the product proved to consist in great part of an oil which could not be made to crystallize. With the hope of obtaining a more satisfactory yield we tried the action of undiluted bromine at a higher temperature. Chlorbromacrylic acid, melting point 68–70°, with a slight excess over the calculated weight of bromine, was heated to 100° for two hours in a closed tube. The excess of bromine was removed by spontaneous evaporation from the product, which was purified by pressure between folds of filter paper and crystallization from carbonic disulphide. By this method from 6.5 grms. chlorbromacrylic acid we obtained 8.5 grms. essentially pure chlortribrompropionic acid, or about seventy per cent of the theoretical amount.

This acid is readily soluble in ether and alcohol, less soluble in cold than in hot carbonic disulphide and chloroform. In contact with water

* These Proceedings, Vol. XVI. p. 240.

it forms an oil which does not solidify at 0°. From carbonic disulphide or chloroform it crystallizes by slow evaporation in oblique prisms of the triclinic system which melt at 102–103°. In the analysis of this substance the following results were obtained: —

I. 0.1582 grm. of the substance gave by the method of Carius, 0.3231 grm. AgCl + AgBr.
II. 0.1582 grm. of the substance gave 0.3251 grm. AgCl + AgBr.
III. 0.9373 grm. of the substance gave 1.9019 grm. AgCl + AgBr. 1.9003 grm. AgCl + AgBr gave 1.1568 grm. Ag.*
IV. 0.8096 grm. of the substance gave 0.3065 grm. CO_2 and 0.0631 grm. H_2O.

Calculated for $C_3H_2ClBr_3O_2$.			Found.				
			I.	II.	III.		IV.
C	10.42						10.32
H	.58						.87
Cl + 3 Br	79.75		79.58	80.00			
Cl	10.28	79.75			9.62	79.36	
Br	69.47				69.74		

The barium, calcium, and potassium salts of this acid were made and analyzed.

Baric chlortribrompropionate $Ba(C_3HClBr_3O_2)_2$.

To form the barium salt a solution of the acid was neutralized with baric carbonate and baric hydrate, filtered, and concentrated by spontaneous evaporation at the ordinary temperature. The salt crystallized in slender oblique prisms which were quite soluble in cold water. The air-dried salt was constant when heated to 80°.

I. 0.6933 grm. of the salt dried at 80° gave on ignition with H_2SO_4 0.1920 grm. $BaSO_4$.
II. 0.6440 grm. of the salt dried at 80° gave 0.1793 grm. $BaSO_4$.

Calculated for $Ba(C_3HClBr_3O_2)_2$.		Found.	
		I.	II.
Ba	16.59	16.26	16.37

* This determination was made with the aid of the excellent method devised by Mr. L. P. Kinnicutt. (These Proceedings, Vol. XVI. p. 91.)

The solubility of this salt we determined by the method of V. Meyer. A saturated solution was kept at 20° for three hours, filtered, evaporated to dryness, and the residue ignited with sulphuric acid.

I. 1.8400 grm. solution gave 0.0977 grm. $BaSO_4$.
II. 0.8926 grm. solution gave 0.0470 grm. $BaSO_4$.

These results correspond to the percentages: —

I.	II.
18.82	18.66

Calcic chlortribrompropionate $Ca(C_3HClBr_3O_2)_2$.

To prepare the calcium salt we neutralized a solution of the acid with calcic carbonate and calcic hydrate, and allowed the filtered solution to evaporate spontaneously. From the concentrated solution the salt separated in clustered needles, which, when air-dried, were constant at 80°.

1.0691 grm. of the salt dried at 80° gave on ignition with H_2SO_4 0.1883 grm. $CaSO_4$.

	Calculated for $Ca(C_3HClBr_3O_2)_2$.	Found.
Ca	5.49	5.25

Potassic chlortribrompropionate $KC_3HClBr_3O_2 . H_2O$.

The potassium salt was made by neutralizing a solution of the acid with potassic carbonate and evaporating at the ordinary temperature. This salt crystallized in rhombic prisms which are freely soluble in cold water. It contained one molecule of crystal water which was given up over sulphuric acid.

I. 1.0688 grm. air-dried salt gave 0.0502 grm. H_2O.
II. 1.0428 grm. air-dried salt gave 0.0490 grm. H_2O.
III. 0.9802 grm. of the anhydrous salt gave 0.2201 grm. K_2SO_4.

	Calculated for $KC_3HClBr_3O_2 . H_2O$.	Found. I.	Found. II.
H_2O	4.48	4.70	4.72

	Calculated for $KC_3HClBr_3O_2$	Found. III.
K	10.20	10.08

The silver salt of this acid proved to be so unstable that we did not succeed in preparing it in a form sufficiently pure for analysis. On the addition of argentic nitrate to an aqueous solution of the acid, even in the cold it immediately became turbid from the separation of argentic chloride.

Although the barium salt is comparatively stable, we found that it was slowly decomposed when heated in aqueous solution. In order to identify the products of this decomposition, the acid was distilled with an excess of baric hydrate. The distillate was caught in bromine water, the excess of bromine allowed to evaporate, and the solution extracted with ether. The oily residue left by evaporation of the ether solidified at 0°, and possessed an odor characteristic of the substituted ethans. It would seem probable, therefore, that the volatile product of this decomposition was tribromethylen; but it was formed in such small quantity that further study was rendered extremely difficult. The residue in the retort contained baric chloride in abundance, but it gave no reaction for baric bromide. The formation of tribromacrylic acid is thus rendered extremely probable; but the residue unfortunately was lost before it could be subjected to a more critical examination. Since the summer term soon after closed, we were unable to repeat our work, and it must therefore be reserved for future study.

Chlorbromacrylic acid forms also an addition-product with hydrobromic acid. When it is heated to 100° in a closed tube with concentrated hydrobromic acid, an acid is formed which melts at 80°. Further study of this substance, which is probably chlordibrompropionic acid, will be postponed for the present.

IX.

CONTRIBUTIONS FROM THE CHEMICAL LABORATORY OF HARVARD COLLEGE.

ON CERTAIN SUBSTANCES OBTAINED FROM TURMERIC. — I. CURCUMIN.

By C. Loring Jackson and A. E. Menke.

Presented December 14, 1881.

The chemical study of curcumin, the yellow coloring matter of turmeric, dates from a paper * by A. Vogel, Sr., and Pelletier, published in 1815, although even before this turmeric-paper had been used as a test for alkalies, and its action with boric acid and various salts observed.† No analysis is given in this paper, and the low melting-point (40°) and description of the method of preparation show that the "yellow coloring-matter of turmeric" obtained by Vogel and Pelletier was principally composed of resin and turmeric oil; they proved, however, that it contained no nitrogen, and studied its action with alkalies, acids, and certain salts, especially acetate of lead.

In 1842 A. Vogel, Jr.,‡ analysed a similar but perhaps somewhat purer preparation, which, however, must have consisted in great part of the yellow resin contained in the root, as it also melted at 40°; it is not wonderful, therefore, that his analyses led to no formula.

Passing over a number of unimportant notices,§ we come next to a

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* Journal de Pharmacie, i. p. 289.

† Trommsdorff, Trommsdorff's Journal von Pharm., xvi. p. 96. Sementini, Bibliothèque Britannique, Jan. 1815.

‡ Journ. de Pharm. et de Chim., sér. 3, ii. p. 20.

§ Desfosses, Ann. Chim. Phys., xvi. p. 76; A. Vogel, Jr., Répert. Pharm., sér. 3, iii. p. 178; H. Rose, Pogg. Ann., cii. p. 545; Lepage, Archiv der Pharm., Ser. 2, xcvii. p. 240; Leube, Vierteljahrsschr. pr Pharm., ix. 395; Alex. Müller, J. pr. Chem. lxxx. p. 119; Wittstein, Vierteljahrsschr. pr. Pharm., ix. p. 282; Schutzenberger, Paraf. Mul. Soc. Bull., 1861, p. 503; Ludwig, Archiv der Pharm., cvi. p. 169; Kraut, Zeitschr. anal. Chem., iv. p. 168.

paper by Schlumberger,* in which the action of a mixture of sulphuric and boric acids on crude curcumin is studied, and a description given of the product called by him rosocyanin, because it dissolved in alcohol with a fine red color, and was turned blue by alkalies. He also describes a resinous product of the action of boric acid on curcumin (pseudocurcumin).

Two years later, in 1868, Bolley, Suida, and Lange † examined the turmeric oil, and published a new analysis of a purer curcumin (melting-point 120°); but it was not till 1870 that curcumin was obtained essentially pure. In this year Daube,‡ Ivanow-Gajewsky,§ and Kachler ‖ published independent papers on the subject, of which Ivanow-Gajewsky's is entitled to the precedence, as the number of the Berlin Berichte which contained Daube's original paper gave a notice in the Correspondence of the reading of Gajewsky's paper before the Russian Chemical Society a month earlier. In addition to an analysis of the turmeric oil, he assigns, as the simplest possible, the formula C_4H_4O to curcumin, which after crystallization from ether or benzin melted at 172°. Daube, on the other hand, after extracting his curcumin with benzol, and purifying it by conversion into the lead salt, obtained the melting-point 165°, and the formula $C_{10}H_{10}O_3$. He also found that it was decolorized by sodium amalgam and alcohol, and converted into oxalic acid by dilute nitric acid.

Kachler, who did not succeed in crystallizing his curcumin, although both Ivanow-Gajewsky and Daube got crystals, obtained the same formula as the former, that is, C_4H_4O, or some multiple of it. He also studied the action of sodium amalgam upon it, and that of hot zinc dust, but with no very definite results in either case; whereas by fusing curcumin with potassic hydrate, he obtained protocatechuic acid. From the turmeric oil he obtained essentially the same analytical results as Ivanow-Gajewsky.

In 1872 Ivanow-Gajewsky published a second paper ¶ on turmeric, containing another method for extracting curcumin, which, however, gave it a melting-point of 140°, and an analysis of the lead salt supporting his formula $C_{16}H_{16}O_4$ ($= (C_4H_4O)_4$). Moreover he confirmed the results of Kachler with fusing potassic hydrate (protocatechuic acid) and zinc dust, and states that the oil obtained with the latter is identical with turmeric oil, of which a new analysis is given, and its

* Bull. Soc. Chim. sér. 2, v. p. 194.
† J. pr. Chem., ciii. p. 474.
‡ Ber. d. ch. G., 1870, p. 609.
§ Ibid., 1870, p. 624.
‖ Ibid., 1870, p. 713.
¶ Ber. d. ch. G., 1872, p. 1103.

oxidation (yielding valeric and caproic acids) and action with phosphoric pentachloride studied. He also prepared and analysed rosocyanin, but was unable to find a satisfactory formula for it.

Finally, in 1873, he published the last paper * we have been able to find on this subject, in which he states that curcumin yields on oxidation with potassic dichromate terephthalic acid, and that rosocyanin contains no boron, and, fused with potassic hydrate, yields paraoxybenzoic acid.

In brief, the following facts had been established in regard to curcumin at the time that we began our research upon it: — Its formula was either $C_{10}H_{10}O_3$ or $C_{16}H_{16}O_4$; the highest melting-point observed was 172°; with alkalies it formed reddish-brown salts; with boric and sulphuric acids rosocyanin; it was susceptible of reduction, and gave an oil with zinc dust; by oxidation it yielded oxalic acid or terephthalic acid, and by fusion with caustic potash protocatechuic acid.

Accordingly we first turned our attention to the determination of its formula.

Extraction and Purification of Curcumin.

After several experiments we have adopted the following method as the best and most convenient: — The turmeric oil is first removed from the ground root by treatment with ligroine; † then the curcumin, mixed with a large quantity of resin, is extracted with ether, and finally purified by crystallization from alcohol.

The turmeric used by us has been principally Bengal turmeric, bought of Messrs E. and F. King, of Boston; we have, however, also extracted enough of the Madras turmeric, the only other brand occurring in the Boston market, to assure ourselves of the identity of the curcumin obtained from both.

For a full description and history of turmeric, which consists of the root-stocks of the *Curcuma longa*, a plant of the ginger family, growing in India and other parts of the East, we would refer to Flückiger and Hanbury's Pharmacographia,‡ and to a full botanical article recently published by A. Meyer § in the Archiv der Pharmacie.

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* Ber. d. ch. G., 1873, p. 196.

† In our first experiments we followed Ivanow-Gajewsky, and used carbonic disulphide for this purpose; but we have found that ligroine is not only much cheaper and more agreeable to work with, but yields a purer oil.

‡ Macmillan and Co., London, 1879.

§ Arch. Pharm. Ser. 3, xviii. p. 401.

The extracter was of the form recently described by Scheibler,* as this was the only one of which we have found a description adapted to the thorough extraction of large quantities of material; those forms in which the drug is not kept covered with the extracting liquid being apt to leave the edges partially unacted on. The only modification of Scheibler's apparatus made by us consisted in substituting a cylindrical tin vessel capable of holding 10 kil. of ground turmeric for the smaller glass vessel used by him. With a cooler 78 cm. long, the inner tube of which was a flattened U, also made of tin, the thorough extraction of the 10 kil. of turmeric could be accomplished in little more than a fortnight. The solvent was removed, after it had ceased to act, by forcing out as much as possible of it by air pressure, and then distilling off the rest by filling with steam a jacket which surrounded the vessel containing the turmeric.

The ligroine extract yielded on evaporation a dark yellow oil, amounting on the average to eleven per cent of the weight of the root. The investigation of this substance will be described in a later paper.

The ether extract, a reddish-brown mass, varying in consistency from semi-liquid to solid according to the period of the extraction at which it was obtained, was treated with successive small quantities of cold alcohol, which dissolved the viscous impurities more easily than the curcumin. In very obstinate cases washing with ether was found advantageous; if, on the other hand, the extract was comparatively free from resin, it could be washed with alcohol upon a filter. In either case the residue was purified by recrystallization from alcohol until it showed the constant melting-point 178°.

The average yield of curcumin was 0.3 of one per cent: this, however, is only the amount that can be extracted by the process just described; the quantity contained in the root is much larger, as a considerable amount remained mixed with the resinous impurities, and the green fluorescence of the crude turmeric oil pointed to the presence of some curcumin in this substance.

Composition of Curcumin.

The following combustions were made of the curcumin purified as just described and dried at 100°. In most of these analyses a slight ash was left, the amount of which has been subtracted from the weight of substance before calculating the percentages.

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* Ber. d. ch. G. 1880, p. 338.

I. 0.1106 gr. of substance gave 0.2774 gr. of CO_2 and 0.0563 gr. of H_2O. No ash.

II. 0.2180 gr. gave 0.5450 gr. of CO_2 and 0.1099 gr. of H_2O. Ash 0.0007 gr.

III. 0.2149 gr. gave 0.5376 gr. of CO_2 and 0.1090 gr. of H_2O. Ash 0.0006 gr.

IV. 0.2195 gr. gave 0.5480 gr. of CO_2 and 0.1099 gr. of H_2O. Ash. 0.0006 gr.

V. 0.2743 gr. gave 0.6815 gr. of CO_2 and 0.1378 gr. of H_2O. Ash 0.0010 gr.

	I.	II.	III.	IV.	V.	Mean.
Carbon	68.43	68.39*	68.42*	68.27*	68.00*	68.30
Hydrogen	5.65	5.62	5.69	5.59	5.60	5.63

All these analyses were made with curcumin from Bengal turmeric: I. and II. of different portions of the same sample, III., IV., and V. of different samples.

The following analysis was made of curcumin extracted from Madras turmeric: —

0.3467 gr. gave 0.8612 gr. of CO_2 and 0.1870 gr. of H_2O. No ash.

Carbon	67.74
Hydrogen	5.99

The sample analysed was very red, and the somewhat lower percentage of carbon obtained was undoubtedly due to the presence of an impurity which causes the curcumin to crystallize in red burrs, as is shown by the following analysis of a very red sample of Bengal curcumin: —

0.2168 gr. of substance gave 0.5400 gr. of CO_2 and 0.1057 gr. of H_2O. No ash.

Carbon	67.93
Hydrogen	5.42

* These numbers become, if the ash is not subtracted from the weight of the substance: —

	II.	III.	IV.	V.
Carbon	68.17	68.23	68.09	67.75
Hydrogen	5.60	5.64	5.56	5.58

It is to be observed, however, that enough of this impurity to change the crystalline habit and color of the curcumin has but a very slight effect on the percentage composition, and, it may be added, does not lower the melting-point more than one degree. That it is formed by the oxidation of curcumin by the action of the air, appears from the fact that pure yellow curcumin was partially converted into red burrs when moistened with alcohol and exposed to the air for a long time. When once formed, the impurity can be removed only by repeated crystallization, and the amount of Madras curcumin at our disposal did not admit of this, nor did we take the trouble to prepare a larger supply, as the above analysis with the melting-point 178° is sufficient to establish the identity of the Madras and Bengal curcumins.

The following comparison shows that our results agree tolerably well with those of Daube, but are entirely at variance with those of Kachler and Ivanow-Gajewsky. (As no analyses are given in the abstract of the latter's article, which alone is at our disposal, we have given the theory for his formula, $C_{16}H_{16}O_4$, under his name.)

	Ivanow-Gajewsky	Kachler		Daube			Jackson and Menke Mean
Carbon	70.58	69.90	69.87	67.90	67.89	67.92	68.30
Hydrogen	5.90	5.70	5.59	5.66	5.76	5.70	5.63

There are, then, eight analyses of curcumin, which support a percentage of carbon in the neighborhood of 68 against three (or more) in favor of one near 70.*

It is probable that the high results obtained by Ivanow-Gajewsky and Kachler were due to the presence of resinous impurities, since their predecessors, who analysed exceedingly impure curcumin, as shown by the low melting-point, obtained the following results.

	A. Vogel, Jr.	Bolley, Suida, and Lange
Carbon	69.50	69.07
Hydrogen	7.46	6.40

This view is further supported by the fact that we obtained a higher melting-point, 178°, than any one else; Daube found 165°, Ivanow-Gajewsky 172°, later 140°, while Kachler gives no melting-point,

* Ivanow-Gajewsky obtained a percentage of lead in a plumbic salt agreeing with his combustion; but this result is more than counterbalanced by the analyses of derivatives of curcumin given later in this paper.

and did not succeed in obtaining his curcumin crystallized. In view of these facts we feel no hesitation in rejecting all the previous analytical results except those of Daube.

Daube gives curcumin the formula $C_{10}H_{10}O_3$, but our results, and for that matter his, agree much better with the formula $C_{14}H_{14}O_4$, as appears from the following comparison: —

	$C_{10}H_{10}O_3$	$C_{14}H_{14}O_4$	Daube	Jackson & Menke
Carbon	67.42	68.29	67.90	68.30
Hydrogen	5.62	5.69	5.70	5.63

We have therefore adopted the formula $C_{14}H_{14}O_4$, which is also confirmed by the analyses of derivatives of curcumin to be given later in the paper.

Properties of Curcumin.

Curcumin crystallizes from alcohol in stout needles, which under the microscope appear as well-formed prisms with square ends, or spindle-shaped crystals, often arranged in radiating groups; in color it is orange to yellow, according to the size of the crystals, with a beautiful blue reflex; its solution in ether exhibits a very strong green fluorescence; when pure it has no odor; it melts at 178°, apparently with decomposition.* It is nearly insoluble in water, somewhat soluble in cold, more readily in hot alcohol and methyl alcohol, more soluble in glacial acetic acid than in alcohol, less so in ether, very slightly soluble in benzol † and carbonic disulphide, and essentially insoluble in ligroine. Strong sulphuric acid dissolves it with a fine reddish-purple color, which changes to black from charring after some time; strong hydrochloric acid produces the same effect, but with more difficulty. It is readily soluble in alkalies and alkaline carbonates, and is even dissolved to a slight extent when boiled with precipitated calcic carbonate and water. The solution in ammonic hydrate loses ammonia when boiled, and deposits unaltered curcumin. A solution of baric hydrate converts it into a blackish-red powder, but lime-water gives a red solution like that obtained from calcic carbonate. It is not affected by acid sodic sulphite.

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* Daube found 164°; Gajewsky, 172° or 140°.

† Compare Daube, Ber. d. ch. G. 1870, p. 609.

Salts of Curcumin.

In taking up the study of this subject we were at first attracted to the lead salt by the analyses and descriptions of Ivanow-Gajewsky and Daube; but, after several experiments, we decided that it was too indefinite a substance to throw much light upon the nature of curcumin, and accordingly turned our attention to the potassium salts, which at first did not seem promising, but on proper treatment have yielded satisfactory results. Before describing these, however, we will say, that there seem to be at least two lead salts, as we have obtained a dark claret precipitate and also a flame-colored one. The most promising method of preparation seemed to be boiling curcumin with precipitated calcic carbonate and water, and adding plumbic acetate to the filtrate; in this way the flame-colored salt was obtained.

We have succeeded in obtaining two potassium salts, containing one and two atoms of potassium respectively.

Dipotassic Salt of Curcumin $K_2C_{14}H_{12}O_4$.

This was made by adding a large excess of a strong alcoholic solution of potassic hydrate to a hot saturated solution of curcumin in alcohol; if the solutions are strong enough, flame-colored crystals of the salt are deposited on cooling; if this is not the case, it can be precipitated by addition of ether. If an insufficient amount of potassic hydrate is used, a dark red solution of the monopotassic salt is formed, which becomes lighter on the addition of more potassic hydrate as the second atom of potassium is taken up. The salt was crystallized from boiling alcohol to which a few drops of ether had been added, washed with a mixture of alcohol and ether, then with ether alone, pressed on filter-paper, and dried as rapidly as possible in a steam-drying closet containing some potassic hydrate.

0.7168 gr. of the salt gave, heated with sulphuric acid, 0.3824 gr. of K_2SO_4.

0.2675 gr. gave 0.1459 gr. of K_2SO_4.

	Calculated for $C_{14}H_{12}K_2O_4$	Found.	
Potassium	24.27	23.95	24.48

If curcumin had the formula $C_{16}H_{16}O_4$ the dipotassic salt would contain,

Potassium 22.46.

The salt consists when first formed of flame-colored needles in globular radiating groups, but becomes deep claret on drying. It is freely soluble in water, not quite so soluble in alcohol, and essentially insoluble in ether; the alcoholic solution takes on a magenta color when exposed to the air, and the salt seems to absorb carbonic dioxide readily, although the change of color was more probably due to oxidation.

Monopotassic Salt of Curcumin $KC_{14}H_{13}O_4$

If an excess of potassic carbonate is added to a hot solution of curcumin in absolute alcohol, there is a violent effervescence, and the liquid turns deep blood red. After slight concentration the excess of potassic carbonate was removed by filtration, the salt precipitated with ether, and purified by washing with ether. An attempt to crystallize it from a mixture of alcohol and ether gave no satisfactory result. Pressed between filter-paper, and then dried at 100°, it gave the following results: —

I. 0.4808 gr. of the salt gave after ignition with sulphuric acid 0.1540 gr. of K_2SO_4.
II. 0.5381 gr. of the salt gave 0.1680 gr. of K_2SO_4.

	Calculated for $KC_{14}H_{13}O_4$	Found. I.	Found. II.
Potassium	13.76	14.36	14.02

$KC_{16}H_{15}O_4$ contains 12.60 per cent of potassium.

The salt is precipitated in crimson black flocks, which dry to a mass having the green color and lustre of rosanilin, although the shade is somewhat blacker. It is very easily soluble in water and alcohol, giving blood-red solutions, but insoluble in ether, and does not seem to be altered by exposure to the air. It can also be made by the action of an excess of curcumin on the dipotassic salt, or by adding potassic hydrate not in excess to curcumin suspended in alcohol. It is very much more soluble than the dipotassic salt.

Curcumin forms also a flame-colored calcium salt, slightly soluble in water, which can be made by adding calcic chloride to a solution of the monopotassic salt. The same salt is formed in small quantity when calcic carbonate is boiled with curcumin and water or alcohol, carbonic dioxide being set free.

The zincic salt seems to be soluble, the baric salt insoluble,* while the silver salt is probably very unstable, as curcumin is decomposed when boiled for more than a minute with argentic nitrate and alcohol. The fact that only one atom of the hydrogen contained in curcumin can be replaced by the potassium of potassic carbonate would point to the existence of one, and only one, carboxyl group in its molecule; the presence of this group is confirmed farther by the power of decomposing calcic carbonate possessed by curcumin.† The replacement of a second atom of hydrogen when curcumin is treated with potassic hydrate in excess indicates the existence of a hydroxyl group, probably a phenol hydroxyl, and it would seem, therefore, that curcumin is a diatomic monobasic acid.

Esters of Curcumin.

Although the analyses of the potassium salts had agreed with the formula of curcumin derived from the analysis of the original substance, it seemed desirable to confirm this formula still farther by the study of some derivative of curcumin more stable and easily handled than the salts; we accordingly took up the investigation of the esters, but found that the ethyl ester made by the action of ethyliodide on the dipotassic salt was a disagreeable brownish-black tarry substance, that could not be obtained in a crystalline condition. We therefore abandoned the study of this substance and turned our attention to the monoparabrombenzyl ester, which we preferred to the benzyl ester, in the first place because of the great tendency of the parabrombenzyl compounds to crystallize, and secondly, since the presence of bromine increased the difference between the percentages of carbon in the two formulas by more than five tenths of one per cent, and also gave a third element whose quantity could be determined.

Monoparabrombenzyl Ester of Curcumin $C_{14}H_{13}(C_7H_6Br)O_4$.

To an alcoholic solution of the monopotassic salt of curcumin an excess of parabrombenzylbromide was added, and the mixture allowed

* As our work on the potassium salts had achieved the end for which we undertook the study of the salts of curcumin, we thought it not worth while to purify any of the other salts for analysis.

† Some experiments on the action of phosphorous trichloride upon monoethylcurcumin confirmed the presence of a carboxyl group, as far as they went, but the product was too ill-defined to repay a thorough study.

to stand for several days, when it was found that pale yellow crystals mixed with potassic bromide had been deposited; the dark-colored liquid was poured off, and the solid residue freed from parabrombenzylbromide by repeated treatment with hot ligroine, and from curcumin by boiling with successive portions of aqueous potassic carbonate, until it ceased to give a red solution. The essentially pure ester thus obtained was boiled several times with alcohol, which dissolved a small portion of it, while the residue melted to a reddish-black tar; upon dissolving this in glacial acetic acid and precipitating with water, yellowish flocks were thrown down, the melting-point of which was compared with that of the similarly-colored indistinct crystals obtained by cooling the alcoholic extract. As both these substances melted, or, more accurately, drew together, at the same temperature, the ester seemed to be essentially pure, and after drying at 50°–60° was analysed.

I. 0.1796 gr. of substance gave 0.3980 gr. of CO_2 and 0.0817 gr. of H_2O.

II. 0.2506 gr. of substance gave according to Carius 0.1156 gr. of AgBr.

	Found.	Calculated for	
		$C_{14}H_{13}(C_7H_6Br)O_4$	$C_{16}H_{15}(C_7H_6Br)O_4$
Carbon	60.43	60.72	62.58
Hydrogen	5.05	4.57	4.76
Bromine	19.63	19.26	18.14

From these results there can be no doubt that $C_{14}H_{14}O_4$ is the true formula of curcumin.

The ester consists of indistinct crystals, grouped in forms like cauliflowers, of a much paler yellow color than curcumin; it melts at 76°–78°, beginning to draw together at 76°, and becoming thoroughly liquid at 78°; we have not succeeded in obtaining it with a perfectly sharp melting-point. It is more soluble in glacial acetic acid than in alcohol, nevertheless the latter is to be preferred as a solvent for obtaining crystals, since the substance is apt to separate from the hot glacial acetic acid in a fused tarry condition. It is readily soluble in ether and benzol, but does not crystallize well from these solvents; slightly soluble in carbonic disulphide; essentially insoluble in ligroine; not attacked by a solution of potassic carbonate, but soluble in potassic hydrate, although without the red color characteristic of curcumin. As the analysis of this ester establishes our formula, we have not continued the study of the esters.

Oxidation of Curcumin.

Our experiments on this subject can be divided into two classes, those in which we made a complete oxidation of the substance, and those in which a partial oxidation was obtained by using an insufficient amount of the oxidizing agent, or one less energetic.

Complete Oxidation. — As Ivanow-Gajewsky states that he obtained terephthalic acid by the action of potassic dichromate and sulphuric acid on curcumin, we turned our attention first to this experiment. Unfortunately only an abstract of his paper is accessible to us, so that we could not find the exact conditions of his oxidation; we have therefore varied the conditions in several ways, but always with the same result. It will be sufficient to describe a single experiment. Half a gramme of curcumin was mixed with sulphuric acid previously diluted with its own volume of water, and solid potassic dichromate added; the action was extremely violent, accompanied by great evolution of heat and strong effervescence; the gas given off was carbonic dioxide. At the end of the process there was no insoluble substance in the liquid, which was therefore distilled until it was reduced to a small volume. The strongly acid distillate, treated with argentic oxide, after filtering and concentration deposited long flattened needles, which looked exactly like argentic acetate, and were proved to consist of this substance by the following silver determination: —

0.1812 gr. of salt dried at 100° gave 0.1559 gr. of AgCl.

	Calculated for $AgC_2H_3O_2$	Found.
Silver	64.68	64.76

There was no other volatile acid in the distillate, and no organic matter could be found in residue from the distillation. If the action was moderated by using more dilute sulphuric acid, the phenomena were the same, except that it was necessary to start the reaction by the aid of heat. In none of the products of the oxidation of curcumin with potassic dichromate could any terephthalic acid be found, they consisted only of acetic acid and carbonic dioxide.

If curcumin is dropped into fuming nitric acid it dissolves with a hissing noise and formation of nitrous fumes and hydrocyanic acid. The red liquid thus obtained gave no precipitate with water; on evaporation it deposited brownish crystals, principally oxalic acid, but it was not further examined. In this respect we confirm the results of Daube, who also obtained oxalic acid from curcumin and nitric acid.

Incomplete Oxidation. — When curcumin was dissolved in aqueous potassic hydrate, a solution of potassic permanganate added, not in excess, and after the oxidation had ceased, the liquid acidified with sulphuric acid, a strong smell of vanilla was observed. The liquid was accordingly filtered, and the precipitate thoroughly washed with boiling water, the filtrate and wash-water extracted with ether, and the extract treated with acid sodic sulphite, as directed by Tiemann and Haarmann.* The product was an oil, having a strong smell of vanilla and gradually solidifying in circular groups of radiating needles; the amount, however, was extremely small, and none of this product was obtained with an excess of potassic permanganate or when the quantity of curcumin was much more than half a gramme. The same substance was obtained with various weak oxidizing agents, such as bleaching powder and water, potassic ferricyanide with potassic hydrate, and even the action of atmospheric oxygen on curcumin dissolved in potassic hydrate. Of these the mixture of potassic hydrate and potassic ferricyanide gave the best yield, but even this was extremely small, — in fact after uniting the product from all the oxidations made by us, in which over eight grammes of curcumin were used, the quantity was not enough for complete purification. By sublimation, however, and subsequent crystallization from boiling water, it was obtained in white needles resembling in appearance and odor the vanillin from the vanilla-bean and melting at 79°. Vanillin melts at 80°–81°.

In addition to the vanillin there were formed carbonic dioxide, a black amorphous substance with feebly acid properties, perhaps the aldehyd resin of vanillin, as it appeared in largest quantity when no vanillin was obtained, and an acid volatile with steam. We have not as yet made any complete study of these secondary products, because the properties of the humus-like substance are far from inviting, and the amount of the volatile acid is so minute that its isolation in quantity sufficient for analysis would be extremely laborious. We shall, however, return to these substances if we fail in finding easier methods for studying the nature of the side-chain.

As the small yield of vanillin was undoubtedly due to the presence of the phenol hydroxyl, which offered a point of attack for the oxidizing mixture, we next tried to increase our yield by replacing the hydroxyl hydrogen with some radical which would protect it from oxidation, and in this way not only prove that the substance was really

* Ber. d. ch. G. 1875, p. 1115.

vanillin, but also that it was one of the principal products of the oxidation. For this purpose we first tried to make acetylcurcumin by treating curcumin with acetylchloride: this gave a deep bluish-green liquid, which on standing turned brown, and then yielded on addition of water a yellowish precipitate which could not be obtained in crystals, its solutions forming on evaporation a dark-colored varnish. With acetic anhydride no better results were obtained, and as there seemed no prospect of getting a good analysis of the substance, it was at once oxidized with potassic permanganate. The result was not essentially better than that obtained with pure curcumin, and we accordingly turned our attention to the oxidation of diethylcurcumin, which was made by boiling the dipotassic salt with absolute alcohol and a slight excess of ethyliodide for six hours in a flask with a return cooler. On distilling off part of the alcohol and allowing the rest to evaporate spontaneously, the compound is left as a most uninviting brownish-black tar, which when heated with sodic hydrate dissolves with a dark red color resembling that of the alkaline solution of curcumin. Upon treating this solution with potassic permanganate until it was decolorized, filtering from manganic hydrate, and acidifying with sulphuric acid, a yellowish precipitate was obtained, which after two crystallizations from boiling water with bone-black melted at 195°, the melting-point given by Wassermann * for ethylvanillic acid (Tiemann † gives 193°–194°).

The nature of the substance was still further confirmed by the following combustion: —

0.1216 gr. of substance gave 0.2714 gr. of CO_2 and 0.0707 gr. of H_2O.

Calculated for $C_{10}H_{12}O_4$		Found.
Carbon	61.22	60.87
Hydrogen	6.12	6.46

There can be no doubt, therefore, that the substance is ethylvanillic acid, and it was formed in such quantity that it must be considered one of the principal products of the reaction. If the potassic permanganate was not added in excess, and the liquid extracted with ether, crystals of ethylvanillin were obtained, which on sublimation formed an oil solidifying after a short time in large twinned crystals like those

* Ann. Chem Pharm. 179. p. 366.

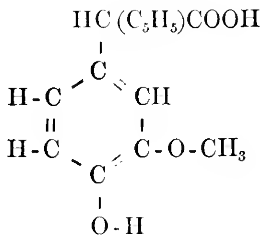
† Ber. d. ch. G. 1875. p 1127.

of cassiterite, and having a smell similar to that of vanillin, but not identical with it.

SUMMARY OF RESULTS.

The formula of curcumin is $C_{14}H_{14}O_4$, as proved by analyses of curcumin itself, of its potassium salts, and its parabrombenzyl ester.

It is a phenol-carboxylic acid, as shown by the study of its salts. The presence of carboxyl is indicated by its power of driving carbonic acid out of potassic and calcic carbonates, and by the decomposition of its diethylester on boiling with potassic hydrate. It contains the vanillin group, and therefore its formula, as far as we have determined it, is: —



We are at present engaged in the study of the group C_5H_5, and propose to extend our investigations to rosocyanin and the turmeric oil.

X.

CONTRIBUTIONS FROM THE CHEMICAL LABORATORY OF HARVARD COLLEGE.

By Henry B. Hill.

Presented February 1, 1882.

I. On Dibromacrylic Acid.

In a communication upon furfurol and certain of its derivatives which I laid before the Academy a year ago, I described a dibromacrylic acid * which O. R. Jackson and I had some time before obtained from mucobromic acid by the action of alkalies. Although we had not been able to prepare the acid in a state of perfect purity, still our results seemed to us sufficient for its identification, and since it then appeared that a more extended study of it would interfere with other investigators in the same field, further work upon it had been for the time given up. Not long afterward it became evident that our hesitation upon this account had been quite unnecessary; but it was not until recently that I was able to take up again the study of this acid. I have now obtained results which correct our previous observations in several important particulars.

For the preparation of the acid O. R. Jackson and I used chiefly the barium salt, which crystallized well from water or dilute alcohol, and which gave us constant analytical results. The air-dried salt lost nothing *in vacuo* over sulphuric acid, or when heated to 80°, and the percentage of barium which it contained agreed closely with that required by the formula $Ba(C_3HBr_2O_2)_2$. We therefore with little hesitation considered the salt anhydrous, and were inclined to ascribe the slight loss of weight which we noticed at 100° to a slow decomposition. The acid made from carefully-prepared barium salt crystallized well, melted quite sharply at 83–84°, but on analysis

* These Proceedings, Vol. XVI. (N. S. VIII.) p. 192.

proved to contain too high a percentage of bromine. Since the acid made from the lead salt had given us precisely the same unsatisfactory results, we thought it probable that the impurities which were found in the acid thus made were introduced by a decomposition of the acid itself in its liberation from its salts. A more careful study of this reaction subsequently convinced me, however, that such was not the case. Certainly no carbonic dioxide, bromacetylen, or hydrobromic acid could be detected as resulting from such decomposition when dilute sulphuric acid was added in slight excess to a boiling aqueous solution of the barium salt. I therefore turned my attention to a further purification of the salts.

Since repeated recrystallization of the barium salt failed to give me any much better product, I thought it worth while to determine the variation of composition introduced by one set of crystallizations from water. I therefore dissolved 30 grammes of white well-crystallized salt (A) in 380 cc. of hot water. On cooling 6.5 grms. of the salt (I.) separated, and by successive filtration, evaporation, and cooling I obtained the fractions (II.) 8.9 grms., (III.) 6.9 grms., and (IV.) 4.8 grms., the remaining 2.9 grms. being lost in the filter-papers upon which the successive portions were dried. An analysis of these air-dried salts gave the following results: —

A. 0.5669 grm. substance gave 0.2239 grm. $BaSO_4$.
I. 0.5713 grm. substance gave 0.2276 grm. $BaSO_4$.
II. 0.5139 grm. substance gave 0.2036 grm. $BaSO_4$.
III. 0.5665 grm. substance gave 0.2231 grm. $BaSO_4$.
IV. 0.5003 grm. substance gave 0.1941 grm. $BaSO_4$.

	Calculated for $Ba(C_3HBr_2O_2)_2$.	Calculated for $Ba(C_3HBr_2O_2)_2.H_2O$.	Found. A.	I.	II.	III.	IV.
Ba	23.03	22.35	23.21	23.43	23.29	23.15	22.80

From these results it was evident that the barium salt contained a persistent impurity which could not be removed by fractional crystallization, and that the constancy of its composition was accidental. I next tried the beautifully crystalline acid potash salt which I have already described,* and found that it gave results which were all that could be desired. This salt can easily be made by neutralizing a weighed amount of the ordinary acid melting at 82–84° with potassic

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* Loc. cit. p. 194.

carbonate, and adding to the hot solution an equal amount of the acid dissolved in a little hot water. As the solution cools the salt separates in long silky needles, which after a few recrystallizations from hot water yield an acid whose melting-point is constant. The loss in recrystallization is comparatively small, since the salt is but sparingly soluble in cold water and dissolves very freely in hot. The analyses which I have made of the acid prepared in this way show its perfect purity.

I. 0.2183 grm. substance gave by the method of Carius 0.3573 grm. AgBr.
II. 0.2127 grm. substance gave 0.3476 grm. AgBr.
III. 0.2530 grm. substance gave 0.4137 grm. AgBr.

	Calculated for $C_3H_2Br_2O_2$.	Found.		
		I.	II.	III.
Br.	69.56	69.66	69.56	69.60

The pure acid melts at 85.5–86°, but in other respects does not differ essentially in its physical properties from the product which I have already described. The solubility of the acid was determined by neutralizing with baric carbonate an aqueous solution of the acid prepared according to the method of V. Meyer, and precipitating with sulphuric acid the barium dissolved.

I. 12.7854 grms. of a solution saturated at 17°.5 gave 0.3107 grm. $BaSO_4$.
II. 13.5723 grms. of a solution saturated at 17°.5 gave 0.3303 grm. $BaSO_4$.
III. 10.8488 grms. of a solution saturated at 18° gave 0.2695 grm. $BaSO_4$.
IV. 9.7341 grms. of a solution saturated at 18° gave 0.2434 grm. $BaSO_4$.

According to these determinations the aqueous solution saturated at 17°.5 and 18° contains the following percentages: —

17°.5.		18°.	
I.	II.	III.	IV.
4.80	4.81	4.90	4.94

Baric Dibromacrylate, $Ba(C_3HBr_2O_2)_2 . H_2O$. The barium salt prepared by neutralizing a solution of the pure acid with baric carbonate did not differ in outward appearance from the salt made directly from mucobromic acid by the action of baric hydrate, but proved on analysis to contain a percentage of barium materially lower than that which O. R. Jackson and I had previously obtained, and closely agreeing with that required by one molecule of water of crystallization. When dried by exposure to the air the salt lost nothing over sulphuric acid or when heated to 85°, but by long-continued heat at 100° (75 to 100 hours) or more rapidly at 120° it gave up its crystal water without showing any signs of decomposition.

I. 0.6642 grm. of the air-dried salt gave by precipitation 0.2540 grm. $BaSO_4$.
II. 0.6392 grm. of the air-dried salt gave on ignition with H_2SO_4 0.2434 grm. $BaSO_4$.
III. 0.5300 grm. of the air-dried salt lost at 120° 0.0161 grm. H_2O.
IV. 1.9253 grm. of the air-dried salt lost at 100° 0.0548 grm. H_2O.
V. 1.1582 grm. of the air-dried salt lost at 100° 0.0351 grm. H_2O, and gave by precipitation with H_2SO_4 0.4408 grm. $BaSO_4$.

Calculated for $Ba(C_3HBr_2O_2)_2 . H_2O$.		Found.				
		I.	II.	III.	IV.	V.
Ba	22.35	22.48	22.39			22.38
H_2O	2.94			3.04	2.85	3.03

The solubility of the salt was also determined.

I. 9.4276 grm. of an aqueous solution saturated at 18° gave by precipitation 0.2214 grm. $BaSO_4$.
II. 8.4088 grm. of a solution saturated at 18° gave 0.1917 grm. $BaSO_4$.

According to these determinations the aqueous solution of the salt saturated at 18° contains the following percentages of the anhydrous salt: —

I.	II.
6.00	5.82

Plumbic Dibromacrylate, $Pb(C_3HBr_2O_2)_2 . H_2O$. The lead salt which, according to the analyses made of former preparations, was anhydrous when made from the pure acid by neutralization with plumbic carbonate, or from the acid potassium salt by precipitation with plumbic acetate, likewise proved to contain one molecule of water of crystallization.

I. 0.5972 grm. of the air-dried salt lost at 100° 0.0161 grm. H_2O, and gave by ignition with H_2SO_4 0.2655 grm. $PbSO_4$.

II. 1.0438 grm. substance dried over H_2SO_4 lost at 100° 0.0283 grm. H_2O, and gave by ignition with H_2SO_4 0.4622 grm. $PbSO_4$.

Calculated for $Pb(C_3HBr_2O_2)_2 . H_2O$.		Found.	
		I.	II.
Pb	30.31	30.37	30.25
H_2O	2.61	2.70	2.71

Calcic Dibromacrylate, $Ca(C_3HBr_2O_2)_2 . 3H_2O$. The calcium salt made from the pure acid crystallized in long clustered needles, which gave on analysis results identical with those which O. R. Jackson and I formerly obtained.

I. 2.1502 grm. of the air-dried salt lost at 80–85° 0.2034 grm. H_2O.

II. 1.2264 grm. of the air-dried salt lost at 95–100° 0.1171 grm. H_2O.

III. 1.8124 grm. of the air-dried salt lost at 100° 0.1755 grm. H_2O.

Calculated for $Ca(C_3HBr_2O_2) . 3H_2O$.			Found.	
		I.	II.	III.
H_2O	9.78	9.46	9.55	9.68

I. 0.4393 grm. of the salt dried at 100° gave on ignition with H_2SO_4 0.1199 grm. $CaSO_4$.

II. 0.6161 grm. of the salt dried at 100° gave on ignition with H_2SO_4 0.1674 grm. $CaSO_4$.

Calculated for $Ca(C_3HBr_2O_2)_2$.		Found.	
		I.	II.
Ca	8.03	8.03	7.99

Potassic Dibromacrylate, $KC_3HBr_2O_2$. The analysis of the potassum salt made by neutralizing the pure acid with potassic carbonate showed that it was anhydrous, as it had previously been described.

I. 0.7334 grm. of the salt dried over H_2SO_4 gave on ignition with H_2SO_4 0.2373 grm. K_2SO_4.

II. 0.7507 grm. of the salt dried over H_2SO_4 gave 0.2427 grm. K_2SO_4.

	Calculated for $KC_3HBr_2O_2$	Found. I.	Found. II.
K	14.58	14.53	14.51

Although many unsuccessful attempts had previously been made to prepare brompropiolic acid in a pure state, it seemed to me not impossible that the prolonged action of alkalies in the cold might remove from the dibromacrylic acid a molecule of hydrobromic acid, and that a purer product might thus be obtained. I found, however, that the reaction was extremely slow, at least with baric hydrate. An aqueous solution which contained one molecule of baric hydrate to each molecule of dibromacrylic acid was strongly alkaline even after standing for fifteen days, and gave on acidification and extraction with ether the compound of brompropiolic and dibromacrylic acids which has already been described. After recrystallization from ligroin the substance melted at 103°, and gave on analysis the following result: —

0.2535 grm. substance gave 0.3766 grm. AgBr.

	Calculated for $C_6H_3Br_3O_4$.	Found.
Br.	63.33	63.22

Since I had before noticed that this intermediate product could be obtained from dibromacrylic acid by the action of baric hydrate in the course of a few hours, and that malonic acid was formed even in the cold after the lapse of several months, it was evident that further attempts in this direction were useless.

II. On the Crystalline Form of α Dichloracrylic Acid.

By W. H. Melville.

(Communicated by H. B. Hill.)

Although the physical properties of the β dichloracrylic acid of Wallach * are decidedly different from those which W. Z. Bennett and I found to be characteristic of the dichloracrylic acid made from mucochloric acid,† a difference which appeared to be fully confirmed by a comparison of the salts of the two acids, still it seemed to me desirable to prove with a little more precision the difference between the two. Since Wallach had made no determinations of the solubility of his acid or its salts, and moreover thought ‡ that little weight should be attached to the determinations of crystal-water which he had as yet published, there remained no definite, well-established points of difference except the melting-points (86° and 77°) and a difference in the crystalline form of the potassium salt: one crystallizing in needles, the other in hexagonal plates. Since the β acid had been obtained in measurable crystals and fully described in Wallach's first paper, although we had previously been unable to get measurable crystals of our acid, I made fresh attempts with larger quantities of material than had then been at our disposal. I found that by the slow cooling of a warm, moderately dilute solution in chloroform well-developed crystals could be obtained, although the determination of the crystals was rendered difficult on account of the rapid roughening of their faces when exposed to the air. Dr. W. H. Melville succeeded, however, in making the necessary measurements, and to his kindness I am indebted for the following description. The purity of the material used was determined by analysis.

0.2061 grm. of the substance gave 0.4198 grm. AgCl.

	Calculated for $C_3H_2Cl_2O_2$.	Found.
Cl.	50.36	50.35

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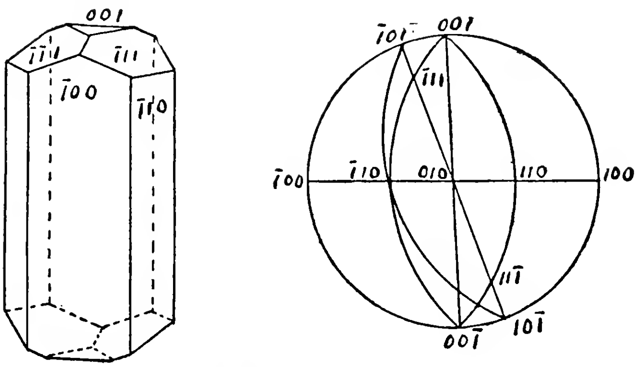
* Ann. Chem. u. Pharm. vol. cxciii. 19.

† These Proceedings, Vol. XVI. (N. S. VIII.) p. 206.

‡ Ann. Chem. u. Pharm. cciii. 83.

CRYSTALLINE FORM OF DICHLORACRYLIC ACID.



Monoclinic System.

Forms, {100} {001} {110} {$\bar{1}$11}.

Elements:	Clinodiagonal	a =	1.1865
	Orthodiagonal	b =	1
	Vertical Axis	c =	0.3637
	Angle of Axes XZ	=	87° 32′

Angles between Normals.

			Observed.	Calculated.
$\bar{1}$11	and	$\bar{1}\bar{1}$1	= 37° 54′	Fundamental angles.
$\bar{1}$11	"	001	= 25° 8′	
$\bar{1}$11	"	$\bar{1}$00	= 71° 49′	
001	"	$\bar{1}$00	= 87° 32′	87° 33′
$\bar{1}$00	"	$\bar{1}$10	= 49° 56′	49° 51′
$\bar{1}$10	"	110	= 80° 6′	80° 18′

Although Wallach's dichloracrylic acid also crystallizes in the monoclinic system, the forms are totally unlike, and the difference between the two acids is therefore established.

III. On the Relation between Dibromacrylic Acid and Tribrompropionic Acids.

By Henry B. Hill and Clement W. Andrews.

Nearly two years ago Michael and Norton * published a description of the tribrompropionic acid melting at 92° which was first mentioned by Linnemann and Penl,† and which they obtained by the addition of bromine to the so-called β monobromacrylic acid of Tollens and Wagner. In this paper they remarked that potassic hydrate attacked the acid readily in alcoholic solution, but they attempted no isolation of the dibromacrylic acid which was thus formed. They soon afterwards offered to relinquish the farther study of this acid, in case we felt interested to undertake its preparation and comparison with the dibromacrylic acid which one of us had already described. This kind offer was accepted, and we began the investigation at once. Although we had no difficulty in the isolation of a dibromacrylic acid which closely resembled that which had been made from mucobromic acid, still it was impossible to establish the identity of the two until the latter had been somewhat more carefully studied. In the mean time Mauthner and Suida, ‡ in an article upon substituted acrylic and propionic acids, described again the preparation of the tribrompropionic acid melting at 92°, without having seen more than a brief notice of Michael and Norton's work. In this article they further showed that it might be converted by the action of potassic hydrate into a dibromacrylic acid, which, as they asserted, was identical with that which O. R. Jackson and one of us had obtained from mucobromic acid.§ The only facts which they brought forward in support of this assertion were, the melting-point, 85°, the ready formation of malonic acid by the action of baric hydrate, and the anhydrous form of the lead salt. Since neither the melting-point nor the action of baric hydrate will discriminate between the two isomeric forms of dibromacrylic acid already known, and moreover since the lead salt of one of these two acids has never been described and of the other is not anhydrous, as one of us has recently shown, it is evident that these facts were wholly insufficient to characterize the acid in question. Our investigation of

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* Amer. Chem. Journ. ii. 18.

† Berichte der deutsch. chem. Gesellsch., viii. 1098.

‡ Sitzungsberichte der kk. Akademie, Wien, lxxxiii. 273.

§ These Proceedings, Vol. XVI. (N. S. VIII.) p. 192.

the same acid has shown us that their assertion, though unsupported by evidence, was accidentally correct.

Dibromacrylic Acid, $C_3H_2Br_2O_2$. In the preparation of the tribrompropionic acid necessary for this research we followed quite closely the method of Michael and Norton, although we did not consider it necessary to purify the dibrompropyl alcohol by distillation under diminished pressure before oxidation. For the conversion of the tribrompropionic acid into the corresponding dibromacrylic acid we have found it most advantageous to dissolve it in the calculated amount of a titrated solution of baric hydrate, and to allow the reaction to proceed at ordinary temperatures. After standing for several days the neutral or at most feebly alkaline solution was evaporated, and the acid extracted from the recrystallized barium salt thus obtained. Since this acid was found by preliminary trial to give a sparingly soluble acid potassium salt which crystallized in long silky needles, for further purification it was converted into this salt. After several recrystallizations from hot water, the acid was set free by the addition of hydrochloric acid and extracted with ether. The acid thus obtained crystallized in small oblique prisms readily soluble in alcohol, ether, and chloroform, more sparingly in benzol or carbonic disulphide. Under water the crystals melted at about 20° to a colorless oil which dissolved readily on heating. The acid dried over sulphuric acid melted at 85–86°, and gave on analysis percentages corresponding to the formula $C_3H_2Br_2O_2$.

I. 0.7497 grm. substance gave on combustion 0.4341 grm. CO_2 and 0.0673 grm. H_2O.

II. 0.2863 grm. substance gave 0.4691 grm. AgBr.

III. 0.2093 grm. substance gave 0.3432 grm. AgBr.

	Calculated for $C_3H_2Br_2O_2$.	Found.		
		I.	II.	III.
C	15.65	15.79		
H	0.87	1.00		
Br	69.56		69.72	69.84

The solubility of the acid we determined by neutralizing with baric carbonate an aqueous solution prepared according to the method of V. Meyer and determining by precipitation the barium dissolved.

I. 12.4640 grms. of a solution saturated at 18° gave 0.3124 grm. $BaSO_4$.

II. 12.2745 grms. of a solution saturated at 18° gave 0.3091 grm. $BaSO_4$.

According to these determinations the aqueous solution saturated at 18° contained the following percentages: —

I.	II.
4.95	4.97

Baric Dibromacrylate, $Ba(C_3HBr_2O_2)_2 . H_2O$. The barium salt made by neutralizing a solution of the acid with baric carbonate crystallized in rhombic plates more or less irregular in form, which when dried by exposure to the air contained one molecule of water.

I. 1.3641 grm. of salt dried over H_2SO_4 gave by precipitation 0.5195 grm. $BaSO_4$.

II. 3.1482 grms. of the air-dried salt lost at 110° 0.0933 grm. H_2O; 0.8202 grm. of the same air-dried salt gave by precipitation 0.3147 grm. $BaSO_4$.

III. 1.7219 grm. of salt dried over H_2SO_4 lost at 120° 0.0520 grm. H_2O; 0.6769 of the same salt gave by precipitation 0.2555 grm. $BaSO_4$.

	Calculated for $Ba(C_3HBr_2O_2)_2 . H_2O$.	Found. I.	II.	III.
Ba	22.35	22.40	22.56	22.19
H_2O	2.94		2.96	3.02

For its further identification we determined its solubility in water at 18°.

9.2373 grm. of a solution saturated at 18° gave by precipitation 0.2131 grm. $BaSO_4$.

From this determination it follows that the aqueous solution saturated at 18° contained 5.89% of the anhydrous salt.

Calcic Dibromacrylate, $Ca(C_3HBr_2O_2)_2 . 3H_2O$. The calcium salt crystallized in clustered needles which contained three molecules of water of crystallization when dried by exposure to the air.

I. 0.5761 grm. of the air-dried salt lost at 80° 0.0535 grm. H_2O.

II. 0.5101 grm. of the air-dried salt lost at 80° 0.0491 grm. H_2O.

	Calculated for $Ca(C_3HBr_2O_2)_2 . 3H_2O$.	Found. I.	II.
H_2O	9.78	9.29	9.63

0.4608 grm. of the salt dried at 80° gave on ignition with H_2SO_4 0.1262 grm. $CaSO_4$.

	Calculated for $Ca(C_3HBr_2O_2)_2$.	Found.
Ca	8.03	8.06

Potassic Dibromacrylate, $KC_3HBr_2O_2$. The potassium salt was made from the acid by neutralization with potassic carbonate. It crystallized in leafy plates which were anhydrous.

0.6842 grm. of the air-dried salt gave on evaporation with H_2SO_4 and ignition 0.2229 grm. K_2SO_4.

	Calculated for $KC_3HBr_2O_2$	Found.
K	14.58	14.62.

A comparison of these results with those which one of us has presented in the preceding paper will be facilitated by the following table, which gives the mean of each series of results: —

	Dibromacrylic Acid from	
	Mucobromic	Tribrompropionic
Melting-point	85.5 – 86°	85 – 86°
Aqueous solution 18°, % acid	4.92	4.96
Barium salt, % water	2.97	2.99
Barium salt solubility 18°	5.91	5.89
Calcium salt, % water	9.56	9.46

Since the identity of the dibromacrylic acid formed by the subtraction of hydrobromic acid from the tribrompropionic acid melting at 92° with that derived from mucobromic acid was thus established with precision, it seemed to us of interest to study a little more closely the tribrompropionic acid which this same dibromacrylic acid forms by the addition of hydrobromic acid. Mr. C F. Mabery * had with one of us already proved that such an addition product could be formed, but it had been prepared solely from the impure acid melting at 83–84° and very little studied. We therefore at first undertook its preparation in larger quantity from pure acid melting at 85–86°.

Tribrompropionic Acid, $C_3H_3Br_3O_2$. When dibromacrylic acid made by the action of baric hydrate upon mucobromic acid is heated with three or four times its weight of hydrobromic acid saturated at 0° for eight or ten hours, at 100° the needle-like prisms disappear and are replaced by rectangular plates of the new tribrompropionic acid. With the pure acid no carbonization such as had been noticed in working with the impure acid was observed even at 120°, and we therefore

* These Proceedings, Vol. XVI. (N. S. VIII.) p. 197.

usually allowed the addition to proceed at this higher temperature, since the reaction was then completed in a shorter time. The tubes opened without marked pressure, and the crystalline product separated from the acid mother-liquors by filtration upon a perforated platinum cone was dried upon porous tiles. When treated in this way the dibromacrylic acid gave about its own weight of crude tribrompropionic acid. The acid can readily be purified by recrystallizing it successively from ligroin and carbonic disulphide. The use of carbonic disulphide causes considerable loss, but with ligroin alone we failed to obtain as high a melting-point. After several recrystallizations the acid showed a constant melting-point, and gave on analysis the required percentages.

I. 1.0329 grm. substance dried over H_2SO_4 gave on combustion 0.4416 grm. CO_2 and 0.0994 grm. H_2O.
II. 0.2184 grm. substance gave 0.3963 grm. AgBr.
III. 0.1938 grm. substance gave 0.3525 grm. AgBr.

	Calculated for $C_3H_3Br_3O_2$.	Found. I.	II.	III.
C	11.57	11.74		
H	0.96	1.07		
Br	77.17		77.29	77.39

This tribrompropionic acid is very soluble in alcohol or ether, somewhat less soluble in chloroform, carbonic disulphide, benzol or ligroin. It dissolves freely in hot water, but is quite rapidly decomposed on boiling with the formation of hydrobromic acid. From the hot aqueous solution the acid crystallizes on cooling in pearly scales. Repeatedly recrystallized from carbonic disulphide, the acid melts at 118°.

Argentic Tribrompropionate, $AgC_3H_2Br_3O_2$. Argentic nitrate added to a cold aqueous solution of the acid precipitates the silver salt in small clustered rhombic plates. On warming it with water argentic bromide is rapidly formed, but it may be dried over sulphuric acid without essential decomposition.

0.2901 grm. of the salt dried over H_2SO_4 gave by precipitation with HBr 0.1316 grm. AgBr.

	Calculated for $AgC_3H_2Br_3O_2$.	Found.
Ag	25.83	26.05

The barium and calcium salts were readily soluble in water, and their solutions could not be warmed without the instantaneous formation of bromide. Even on evaporating their solutions at ordinary temperatures over sulphuric acid *in vacuo* the barium salt was almost wholly decomposed; the calcium salt was apparently somewhat more stable, for it was thus obtained in dendritic needles, although the mother-liquor contained calcic bromide. Since the air-dried salt lost nothing over sulphuric acid and was decomposed by heat, the water of crystallization could not be directly determined. It gave, however, a percentage of calcium agreeing closely with that required by two molecules of water.

I. 1.1087 grm. of the air-dried salt gave on ignition with H_2SO_4 0.2179 grm. $CaSO_4$.

II. 0.7279 grm. of the air-dried salt gave on ignition with H_2SO_4 0.1425 grm. $CaSO_4$.

	Calculated for $Ca(C_3H_2Br_3O_2)_2 . 2H_2O$.	Found. I.	Found. II.
Ca	5.75	5.78	5.76

We were unable to prepare other salts.

Dibromacrylic Acid. The ready decomposition of the tribrompropionic acid made it seem desirable to isolate and identify the dibromacrylic acid which was thus formed. For this purpose we dissolved pure tribrompropionic acid, melting at 118°, in water and added from a burette a titrated solution of baric hydrate. So rapid was the action that an alkaline reaction could not be maintained until nearly one molecule of baric hydrate had been added for each molecule of the acid. When the calculated amount of baric hydrate had been added the solution was allowed to stand for half an hour, and then but a trace of baric carbonate could be precipitated with carbonic dioxide. Ether extracted from the acidified solution a crystalline acid melting at 85–86°, which gave on analysis the percentage of bromine required by the formula $C_3H_2Br_2O_2$.

0.1979 grm. substance gave 0.3240 grm. AgBr.

	Calculated for $C_3H_2Br_2O_2$.	Found.
Br.	69.57	69.66.

The solubility of the acid in cold water was determined by the method of V. Meyer.

I. 10.7793 grms. of a solution saturated at 18° gave on neutralization with baric carbonate and precipitation 0.2908 grm. $BaSO_4$.

II. 7.7354 grms. of a solution saturated at 18° gave 0.1940 grm. $BaSO_4$.

According to these determinations the aqueous solution of the acid saturated at 18° contained the percentages: —

I.	II.
5.32	4.95

Baric Dibromacrylate, $Ba(C_3HBr_2O_2)_2 . H_2O$. By neutralizing the acid with baric carbonate, or more conveniently by the direct evaporation of the solution obtained by the action of baric hydrate upon tribrompropionic acid, we obtained the barium salt in leafy rhombic plates which, when dried over sulphuric acid, contained one molecule of water.

I. 1.1489 grm. of the salt dried over H_2SO_4 lost at 100–105° 0.0335 grm. H_2O.

II. 1.5158 grm. of the salt dried over H_2SO_4 lost at 105–110° 0.0457 grm. H_2O, and gave on precipitation 0.5790 grm. $BaSO_4$.

	Calculated for $Ba(C_3HBr_2O_2)_2 . H_2O$.	Found. I.	Found. II.
Ba	22.35		22.46
H_2O	2.94	2.92	3.02

Calcic Dibromacrylate, $Ca(C_3HBr_2O_2)_2 . 3 H_2O$. The calcium salt crystallized in radiating needles which contained when air-dried three molecules of water.

0.9444 grm. of the air-dried salt lost at 100–105° 0.0906 grm. H_2O, and gave on ignition with H_2SO_4 0.2332 grm. $CaSO_4$.

	Calculated for $Ca(C_3HBr_2O_2)_2 . 3 H_2O$.	Found.
Ca	7.25	7.26
H_2O	9.78	9.59

These results are sufficient to prove that this dibromacrylic acid is identical with the one already studied, as a comparison of the mean results given in the following table will show.

	Dibromacrylic Acid from Mucobromic Acid.	Dibromacrylic Acid from Tribrompropionic.
Melting-point	85.5 – 86°	85 – 86°
Aqueous solution saturated at 18°, % acid	4.92	5.12
Barium salt, % water	2.97	2.97
Calcium salt, % water	9.56	9.59

IV. On Certain Tetrasubstituted Propionic Acids.

By Henry B. Hill and Charles F. Mabery.

In a previous communication * one of us has already mentioned the fact that the dibromacrylic from mucobromic acid, unlike the dichloracrylic acid of Wallach, takes up a molecule of bromine with readiness and forms a tetrabrompropionic acid. We were led to undertake a more complete study of the tetrasubstituted propionic acids, especially with the hope that the study of those containing two different halogens might throw some light upon the position of the halogen atoms in the disubstituted acrylic acids formed from mucobromic and mucochloric acids. After our investigations were concluded Mauthner and Suida † published in the Proceedings of the Vienna Academy a paper entitled "Ueber gebromte Propionsäuren und Acrylsäuren," in which they anticipate us in the publication of a portion of our work. Since they were perfectly well aware that, in studying derivatives of a substituted acrylic acid which they asserted, although without adequate proof, was identical with that obtained from mucobromic acid, they were trespassing upon ground which one of us had already fully reserved, we think it advisable, although it involves a certain amount of repetition, to give our results in full, more especially since we are able to correct their work in several important particulars.

Tetrabrompropionic Acid.

Tetrabrompropionic acid can readily be made by the addition of bromine to dibromacrylic acid at ordinary temperatures.‡ We have prepared it by adding to a solution in chloroform the calculated amount of bromine. On standing, the addition product gradually separates, often in large, well-formed prisms. The amount of the product thus obtained was about 90% of the theoretical yield. After recrystallization from chloroform the substance was dried over sulphuric acid.

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* These Proceedings, Vol. XVI. (N. S. VIII.) p. 197.

† Sitzungsberichte der kk. Akademie, Wien, lxxxiii. 273.

‡ Mauthner and Suida assert that the dibromacrylic acid will take up no bromine in the cold. They prepared tetrabrompropionic acid by heating to 100° with undiluted bromine. That the bromine is very readily taken up one of us first mentioned several years ago (Berichte der deutsch. chem. Gesellsch., l. xii. 657).

I. 0.5480 grm. substance gave 0.1837 grm. CO_2 and 0.0286 grm. H_2O.

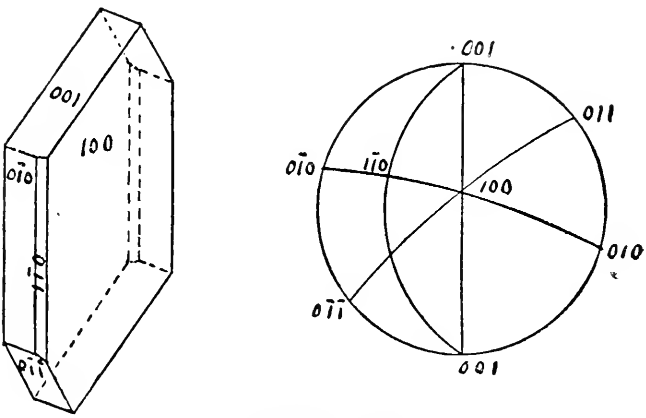
II. 0.1775 grm. substance gave 0.3432 grm. AgBr.

	Calculated for $C_3H_2Br_4O_2$.	Found. I.	Found. II.
C	9.23	9.14	
H	0.51	0.58	
Br	82.04		82.28

Tetrabrompropionic acid crystallizes in prisms of the triclinic system which melt at 125–126°. It is very soluble in alcohol or ether, readily soluble in hot chloroform, carbonic disulphide or benzol, and separates in crystals as these solutions cool. In ligroin it is sparingly soluble. Under water it melts at a very low temperature to a colorless oil which dissolves freely on heating.

For a crystallographic study of the substance we are indebted to Dr. W. H. Melville.

CRYSTALLINE FORM OF TETRABROMPROPIONIC ACID.



Triclinic System.

Forms, {100} {010} {001} {011} {1$\bar{1}$0}.

Elements: Macrodiagonal a = 1.507
Brachydiagonal b = 1
Vertical Axis c = 0.934
Angles of Axes XY = 94° 59′
XZ = 104° 28′
YZ = 74°20′

Angles between Normals.

	Observed.		Calculated.
100 and 010	= 88° 48′	Fundamental angles.	
010 " 011	= 56° 3′		
011 " 001	= 48° 51½′		
100 " 011	= 77° 21½′		
100 " 1$\bar{1}$0	= 57° 25′		
100 " 001	= 77° 1′		76° 21′

Argentic Tetrabrompropionate, $AgC_3HBr_4O_2$. Argentic nitrate added to a solution of the acid in dilute alcohol precipitates the silver salt in clustered needles, which may further be increased in quantity by the cautious addition of ammonic hydrate. The salt is extremely unstable, forms argentic bromide on warming, and blackens rapidly in diffused light.

1.2182 grm. of the salt dried over H_2SO_4 gave 0.4744 grm. AgBr.

	Calculated for $AgC_3HBr_4O_2$.	Found.
Ag	21.78	22.38

Baric Tetrabrompropionate, $Ba(C_3HBr_4O_2)_2 . 2H_2O$. An aqueous solution of the acid dissolved baric carbonate readily in the cold, and if the solution was not warmed there was no noticeable decomposition. On spontaneous evaporation at ordinary temperatures the barium salt was left in clusters of flattened needles. When dried by exposure to the air they contained two molecules of water which they lost over sulphuric acid.

I. 0.7239 grm. of the air-dried salt lost over H_2SO_4 0.0272 grm. H_2O.

II. 0.7087 grm. of the air-dried salt lost over H_2SO_4 0.0259 grm. H_2O.

	Calculated for $Ba(C_3HBr_4O_2)_2 . 2H_2O$.	Found. I.	Found. II.
H_2O	3.79	3.76	3.66

0.6756 grm. of the salt dried over H_2SO_4 gave on ignition with H_2SO_4 0.1742 grm. $BaSO_4$.

	Calculated for $Ba(C_3HBr_4O_2)_2$.	Found.
Ba	14.97	15.16

Calcic Tetrabrompropionate, $Ca(C_3HBr_4O_2)_2$. The calcium salt, made by neutralizing an aqueous solution of the acid with calcic carbonate and allowing the solution to evaporate spontaneously, crystallized in needles which proved to be anhydrous. The salt freed from moisture by pressure did not materially lose in weight when exposed to the air, and when air-dried lost nothing over sulphuric acid.

I. 0.5065 grm. of the salt dried over H_2SO_4 gave on ignition with H_2SO_4 0.0888 grm. $CaSO_4$.

II. 1.0886 grm. of the salt dried over H_2SO_4 gave 0.1850 grm. $CaSO_4$.

Calculated for $Ca(C_3H_2Br_4O_2)_2$.		Found. I.	Found. II.
Ca	4.89	5.16	5.00

When a solution of baric tetrabrompropionate was heated baric bromide was formed, carbonate dioxide escaped, and at the same time the liquid became turbid through the separation of a colorless oil.* On distilling the liquid the oil passed readily over with steam, and since from the method of its formation there could be little doubt that it was tribromethylen, for identification it was immediately converted into its dibromide by the addition of bromine. The crystalline addition product which was thus obtained when purified by recrystallization melted at 53° and gave on analysis a percentage of bromine which showed it to be pentabromethan.

0.1696 grm. substance gave 0.3766 grm. AgBr.

Calculated for C_2HBr_5.	Found.
94.12	94.48

This decomposition may therefore be expressed by the equation:

$$Ba(C_3HBr_4O_2)_2 = BaBr_2 + 2\ CO_2 + 2\ C_2HBr_3.$$

By the action of an alcoholic solution of potassic hydrate upon tetrabrompropionic acid a molecule of hydrobromic acid is removed, and there results the tribromacrylic acid melting at 118° which we have

* Mauthner and Suida assert that this decomposition also takes place on long standing at ordinary temperatures. They were therefore able to isolate no salts. We have never observed any decomposition in the cold. Loc. cit. p. 284.

already described.* Dr. W. H. Melville kindly made a crystallographic study of the crystals which we obtained, and established their identity with those he had previously examined, which were prepared by the addition of bromine to brompropiolic acid. A description of the crystalline form of tribromacrylic acid Dr. Melville presents in a separate communication.

α Dichlorbrompropionic Acid.

In studying the dichloracrylic acid made from mucochloric acid W. Z. Bennett and one of us found that even at 100° it would not take up bromine when dissolved in chloroform.† Subsequently it appeared from the experiments of C. W. Andrews that the substituted propionic acid could readily be made by the action of undiluted bromine, although circumstances at the time prevented a detailed study on his part. As a precise characterization of this addition product seemed of interest we undertook its preparation and investigation.

Pure dichloracrylic acid melting at 85–86° was heated with a molecule of bromine for several hours at 100°. The almost colorless product of the reaction was pressed thoroughly with paper and purified by crystallization, at first from carbonic disulphide, and finally from chloroform. When dried over sulphuric acid this substance gave on analysis percentages agreeing closely with those required by the formula $CH_2Cl_2Br_2O_2$. In the indirect determination of the halogens we used the extremely convenient and accurate method recently described by Mr. L. P. Kinnicutt.‡

I.§ 0.8124 grm. substance gave 0.3550 grm. CO_2 and 0.0665 grm. H_2O.

II. 0.1715 grm. substance gave 0.3775 grm. AgCl + AgBr.

III. 0.4790 grm. substance gave 1.0559 grm. AgCl + AgBr. From this by reduction was obtained 0.6887 grm. Ag.

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* These Proceedings, Vol. XVI. (N. S. VIII.) p. 216. Mauthner and Suida assign to the barium and calcium salts of this acid, prepared by them from tetrabrompropionic acid, formulæ differing greatly from those which we formerly established by our analyses. Since their determinations were made with small quantities of material, we have not thought it necessary to make further analyses in support of our formulæ.

† These Proceedings, Vol. XVI. (N. S. VIII.) p. 211.

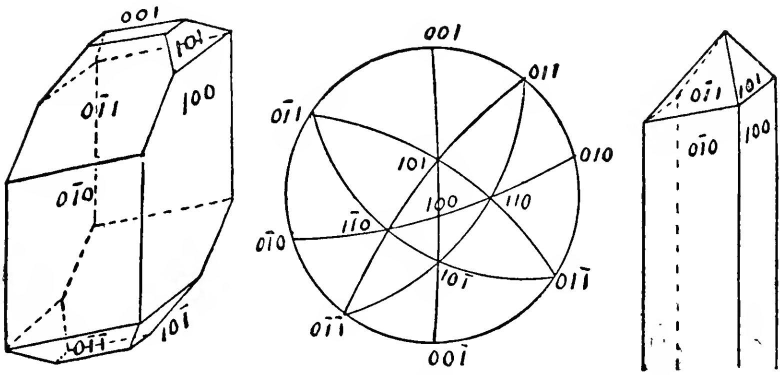
‡ These Proceedings, Vol. XVII. (N. S. XI.) p. 91.

§ These analyses were made by Mr. Andrews.

	Calculated for $C_3H_2Cl_2Br_2O_2$.		Found. I.	II.	III.
C	11.96		11.91		
H	0.67		0.90		
Cl	23.59	76.74		76.93	23.77
Br	53.15				52.90

This α dichlordibrompropionic acid crystallizes in well-formed triclinic prisms, which melt at 94–95°. It is readily soluble in water, alcohol, or ether; in carbonic disulphide, chloroform, or benzol it dissolves less freely. From a solution in carbonic disulphide it could be obtained by slow evaporation in well-formed crystals, whose study was kindly undertaken by Dr. W. H. Melville.

Crystalline Form of α Dichlordibrompropionic Acid.



Triclinic System.

Forms, {100} {010} {001} {101} {011} {10$\bar{1}$} {0$\bar{1}\bar{1}$}; {110} and {1$\bar{1}$0} often present.

* Elements:	Macrodiagonal	a = 1.023
	Brachydiagonal	b = 1
	Vertical axis	c = 1.052
	Angles of axes	XY = 91°
		XZ = 76° 31½′
		YZ = 108° 52′

* Through an error the ratios of the fundamental parameters were originally given in the Berichte der deutsch. chem. Gesellsch. xiv. 1680. a : b : c = 1.034 : 1 : 1.062.

Angles between Normals.

	Observed.	Calculated.
100 and 010 =	93° 37′	Fundamental angles.
100 " 101 =	52° 58′	Fundamental angles.
010 " 011 =	34° 57′	Fundamental angles.
010 " 101 =	77° 19′	Fundamental angles.
101 " 011 =	58° 46′	Fundamental angles.
100 " $10\bar{1}$ =	38° 32′	38° 41′
011 " 001 =	35° 21′	35° 52′
001 " $0\bar{1}1$ =	55° 45′	55° 30′
100 " 011 =	101° 3′	100° 39′
100 " $0\bar{1}1$ =	98° 49′	98° 38′
101 " $\bar{1}01$ =	87° 34′	88° 20′
$10\bar{1}$ " $0\bar{1}\bar{1}$ =	50° 32′	50° 30′

Argentic α Dichlordibrompropionate, $AgC_3HCl_2Br_2O_2$. The silver salt falls, on the addition of argentic nitrate to an aqueous solution of the acid, in flattened jagged needles which are readily decomposed by heat. They could, however, be dried over sulphuric acid without any essential decomposition, as is shown by the following analysis: —

0.4885 grm. of substance gave by precipitation with HBr 0.2231 grm. AgBr.

	Calculated for $AgC_3HCl_2Br_2O_2$.	Found.
Ag	26.46	26.23

Baric α Dichlordibrompropionate, $Ba(C_3HCl_2Br_2O_2)_2$. The barium salt we made by neutralizing a cold aqueous solution of the acid with baric carbonate. On evaporation at ordinary temperatures it crystallized in long branching needles, which when dried by exposure to the air did not lose materially in weight over sulphuric acid, and contained a percentage of barium corresponding to the anhydrous salt.

I. 0.5069 grm. of the air-dried salt gave 0.1606 grm. $BaSO_4$.
II. 0.5239 grm. of the air-dried salt gave 0.1676 grm. $BaSO_4$.

	Calculated for $Ba(C_3HCl_2Br_2O_2)_2$.	Found. I.	Found. II.
Ba	18.59	18.58	18.81

The barium salt is decomposed by warming, its solution giving products similar to those obtained in the same way from tetrabrompropionic acid. This decomposition, however, we have not as yet studied further.

β Dichlordibrompropionic Acid.

Although dibromacrylic acid assumes a molecule of bromine so readily, we found at first great difficulty in preparing the corresponding addition product with chlorine. If chlorine gas is passed into melted dibromacrylic acid it is gradually taken up and the melting-point of the acid is slowly changed. After long-continued action a considerable quantity of the dichlordibrompropionic acid is formed, but so contaminated with oily by-products that its purification is a matter of some difficulty. This addition of chlorine is, however, rapidly and neatly accomplished if the reaction is allowed to proceed in direct sunlight at 100°. When at this temperature the melted acid becomes nearly solid with separating crystals of the addition product, the chlorination is interrupted. The product which we obtained in this way from pure dibromacrylic acid melting at 85–86° was purified by crystallization first from carbonic disulphide and finally from chloroform. On analysis it gave the following results: —

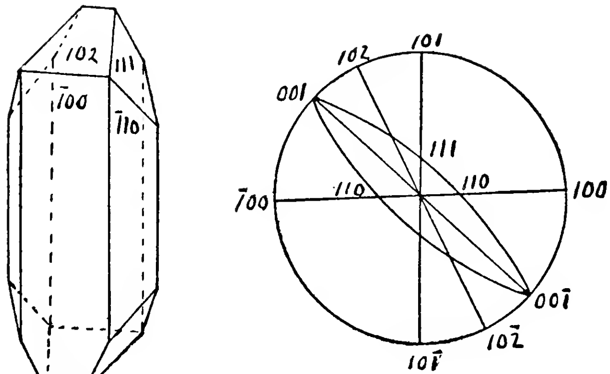
I. 0.5183 grm. substance gave 0.2335 grm. CO_2 and 0.0431 grm. H_2O.

II. 0.1547 grm. substance gave 0.3400 grm. AgCl + AgBr. From this by reduction was obtained 0.2214 grm. Ag.

	Calculated for $(C_3H_2Cl_2Br_2O_2)$.	Found.	
		I.	II.
C	11.96	12.13	
H	0.66	0.92	
Cl	23.59		23.37
Br	53.15		53.21

This *β* dichlordibrompropionic acid crystallizes in oblique prisms which melt at 118–120°, and in its behavior with solvents closely resembles the *α* acid. In water, alcohol, or ether it dissolves very easily, but with somewhat more difficulty in carbonic disulphide, chloroform, or benzol. The solution in carbonic disulphide gave by slow evaporation well-developed crystals whose elements Dr. W. H. Melville kindly determined.

CRYSTALLINE FORM OF β DICHLORDIBROMPROPIONIC ACID.



Monoclinic System.

Forms, {100} {110} {111} {102}

Elements:	Clinodiagonal	a = 2.393
	Orthodiagonal	b = 1
	Vertical axis	c = 1.731
	Angle of axes XZ	= 46° 9

Angles between Normals.

	Observed.	Calculated.
110 and $\bar{1}10$ =	60° 11′	Fundamental Angles.
111 " $\bar{1}10$ =	42° 24½′	
111 " 110 =	40° 33½′	
$\bar{1}00$ " $\bar{1}10$ =	59° 53′	59° 54½′
111 " $1\bar{1}1$ =	120° ½′	119° 56′
100 " 111 =	88° 57′	88° 47′
102 " $\bar{1}10$ =	102° 21′	102° 23′
102 " 110 =	78° 5′	77° 37′
102 " 111 =	63° 44′	63° 42½′

The difference between the α and β acids was further confirmed by a study of the silver and barium salts.

Argentic β Dichlordibrompropionate, $AgC_3HCl_2Br_2O_2$. The silver salt is precipitated in the form of short, thick, pointed prisms when argentic nitrate is added to an aqueous solution of the acid. It is readily decomposed by heat, but may be dried for analysis over sulphuric acid.

0.4950 grm. of the salt gave on precipitation with HCl 0.1731 grm. AgCl.

	Calculated for $AgC_3HCl_2Br_2O_2$.	Found.
Ag	26.46	26.31

Baric β Dichlordibrompropionate, $Ba(C_3HCl_2Br_2O_2)_2 . 2H_2O$. The barium salt which we made by neutralizing an aqueous solution of the acid with baric hydrate crystallized on spontaneous evaporation of its solution in long radiating needles which were very soluble in cold water. When dried by exposure to the air the salt proved to contain two molecules of water which it lost over sulphuric acid.

I. 1.6201 grm. of the air-dried salt lost over H_2SO_4 0.0705 grm. H_2O.
II. 1.5443 grm. of the air-dried salt lost over H_2SO_4 0.0731 grm. H_2O.

	Calculated for $Ba(C_3HCl_2Br_2O_2)_2 . 2 H_2O$.	Found. I.	Found. II.
H_2O	4.66	4.35	4.74

0.8236 grm. of the salt dried over H_2SO_4 gave 0.2619 grm. $BaSO_4$.

	Calculated for $Ba(C_3HCl_2Br_2O_2)_2$.	Found.
Ba	18.59	18.69

These results prove that the α and β dichlordibrompropionic acids described are essentially different.

	Dichlordibrompropionic Acid. α	Dichlordibrompropionic Acid. β
System of Crystallization....	Triclinic.	Monoclinic.
Melting-point	94 – 95°	118 – 120°
Barium salt	$Ba(C_3HBr_2Cl_2O_2)$	$Ba(C_3HBr_2Cl_2O_2)_2 . 2 H_2O$.

The barium salt was readily decomposed by warming its aqueous solution. Baric chloride and carbonic dioxide were formed together with a colorless oil which undoubtedly was a dibromchlorethylen. With bromine this oil gave a solid addition product, which, however, we have not as yet prepared in quantity sufficient for complete purification and identification.

V. On the Constitution of the Substituted Acrylic and Propionic Acids.

By Henry B. Hill.

Within a few years the number of substituted acrylic and propionic acids known has been largely increased, and yet the constitution of but few of these can be said to be satisfactorily established. In a previous communication I was led to adopt provisionally for mucobromic acid the formula, —

$$\begin{array}{l} \quad CBr_2 - CHO \\ \quad \;\; | \\ = C - COOH \end{array}$$

which explained its connection with maleic acid, in whose molecule the researches of Fittig had shown the provable existence of a dyad carbon atom. The structure of the related dibromacrylic acid was then naturally expressed by the formula, —

$$\begin{array}{l} CBr_2H \\ | \\ C = \\ | \\ COOH \end{array}$$

against which at the time nothing more convincing than a belief in its improbability could be urged. The relations which Andrews and I have shown to exist between this same acid and two different tribrompropionic acids prove, however, that this formula is incorrect. An acid with this structure could be formed from but a single tribrompropionic acid, and must of necessity give this same tribrompropionic acid by the addition of hydrobromic acid. The same objection also applies with equal force to the other two conceivable formulæ for dibromacrylic acid which contain dyad carbon, —

$$\begin{array}{l} = CH \\ \quad | \\ \quad CBr_2 \\ \quad | \\ \quad COOH \end{array} \qquad \text{and} \qquad \begin{array}{l} = CBr \\ \quad | \\ \quad CHBr \\ \quad | \\ \quad COOH \end{array}$$

and these must consequently be rejected. There remain therefore for the acid in question but two possible formulæ, —

$$\begin{array}{l} \mathrm{CBr_2} \\ \| \\ \mathrm{CH} \\ | \\ \mathrm{COOH} \end{array} \qquad \text{and} \qquad \begin{array}{l} \mathrm{CHBr} \\ \| \\ \mathrm{CBr} \\ | \\ \mathrm{COOH} \end{array}$$

The formation of two isomeric dichlordibrompropionic acids by the addition of chlorine to the dibromacrylic acid and of bromine to the analogous dichloracrylic acid, as Mabery and I have shown, would seem again to be decisive in favor of the first of these formulæ, since its adoption would give, —

$$\begin{array}{l} \mathrm{CBr_2Cl} \\ | \\ \mathrm{CHCl} \\ | \\ \mathrm{COOH} \end{array} \qquad \text{and} \qquad \begin{array}{l} \mathrm{CCl_2Br} \\ | \\ \mathrm{CHBr} \\ | \\ \mathrm{COOH} \end{array}$$

as the structure of the two isomeric dichlordibrompropionic acids, while the second formula would give in either case the same compound, —

$$\begin{array}{l} \mathrm{CHBrCl} \\ | \\ \mathrm{CBrCl} \\ | \\ \mathrm{COOH} \end{array}$$

Although it was by no means impossible that a molecular rearrangement had taken place in one of these two reactions, still it seemed improbable, since the reactions were apparently neat, and in the treatment with chlorine, where such a change would be more naturally expected, no bromine could be detected in the escaping chlorine.

On the other hand the adoption of the formulæ, —

$$\begin{array}{l} \mathrm{CBr_2} \\ \| \\ \mathrm{CH} \\ | \\ \mathrm{COOH} \end{array} \qquad \text{and} \qquad \begin{array}{l} \mathrm{CCl_2} \\ \| \\ \mathrm{CH} \\ | \\ \mathrm{COOH} \end{array}$$

for the derivatives of mucobromic and mucochloric acids presented difficulties quite as serious. In the first place the dichloracrylic acid of Wallach had been proved beyond all doubt to be different from that which Bennett and I had described by a comparison of the crystalline form of the two acids, and it would follow then that Wallach's acid could not have the formula he assigned to it. The formation of an acid with different structure from chloralid could, however, be explained upon the assumption that the chlorpropiolic acid was the first product of the reduction, and that this passed, on the one hand by the addition of hydrogen, into the β chloracrylic acid, and on the other hand formed dichloracrylic acid by addition in the subsequent treatment with strong hydrochloric acid which Wallach prescribes.* Although this hypothesis was far from satisfactory, it seemed to me hardly more improbable than that a similar molecular rearrangement had taken place in the reaction which had come under my own observation.

Still another difficulty was to be found in the formation of the dibromacrylic acid in question from the tribrompropionic acid melting at 92°, which, if the ordinarily accepted formula for the latter, —

$$\begin{array}{c} CH_2Br \\ | \\ CBr_2 \\ | \\ COOH \end{array}$$

were correct, would prove the incorrectness of the formula assumed. I was at first unable to attach any great importance to this argument, inasmuch as the constitution of the monobromacrylic acids was extremely uncertain. For although the discovery by Wallach of the β monobromacrylic acid melting at 115° had rendered the constitution of the α and β monobromacrylic acids of Tollens extremely doubtful, it by no means proved their identity.

Erlenmeyer has, however, recently shown† that the α and β acids of Tollens, as well as their potassium salts, crystallize in identical forms, and the structure of the tribrompropionic acid melting at 92° is therefore put upon quite another footing. Since the same (α) monobromacrylic acids can be made from α dibrompropionic and also from its isomer, the α β dibrompropionic, it follows that this acid must have the structure, —

* Ann. Chem. u. Pharm., xcxiii. 7.

† Berichte der deutsch. chem. Gesellsch., xiv. 1867.

$$\begin{array}{c} \mathrm{CH} \\ \| \\ \mathrm{CBr} \\ | \\ \mathrm{COOH} \end{array}$$

and the tribrompropionic acid made from it by the addition of bromine must of course have the corresponding form, —

$$\begin{array}{c} \mathrm{CH_2Br} \\ | \\ \mathrm{CBr_2} \\ | \\ \mathrm{COOH} \end{array}$$

Since the formulæ with dyad carbon are in this case excluded, there remains for the dibromacrylic acid in question only the structure, —

$$\begin{array}{c} \mathrm{CHBr} \\ \| \\ \mathrm{CBr} \\ | \\ \mathrm{COOH} \end{array}$$

Although this conclusion is directly at variance with the results which Mabery and I obtained in the study of the dichlordibrompropionic acids, it must be confessed, I think, that it is probably correct. Still, since its adoption presents undoubted difficulties, I shall endeavor to bring more direct experimental evidence as to its correctness.

The dibromacrylic acid of Fittig and Petri, which, as Mabery and I have shown, can be made from brompropiolic acid, would naturally have the form, —

$$\begin{array}{c} \mathrm{CBr_2} \\ \| \\ \mathrm{CH} \\ | \\ \mathrm{COOH} \end{array}$$

and the acids made in the same way containing two halogens the corresponding, —

$$\begin{array}{c} \mathrm{CBrI} \\ \| \\ \mathrm{CH} \\ | \\ \mathrm{COOH} \end{array} \qquad\qquad \begin{array}{c} \mathrm{CBrCl} \\ \| \\ \mathrm{CH} \\ | \\ \mathrm{COOH} \end{array}$$

The tribrompropionic acid melting at 118° would be written, —

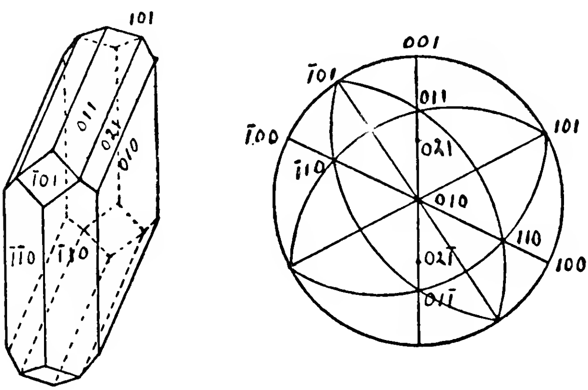
$$
\begin{array}{c}
CHBr_2 \\
| \\
CHBr \\
| \\
COOH
\end{array}
$$

and the tetrabrompropionic acid would have the form, —

$$
\begin{array}{c}
CHBr_2 \\
| \\
CBr_2 \\
| \\
COOH
\end{array}
$$

VI. Crystalline Form of Tribromacrylic Acid.

By W. H. Melville.



Monoclinic System.

Forms, $\{010\}$ $\{110\}$ $\{011\}$ $\{101\}$ $\{\bar{1}01\}$ $\{021\}$; the last three forms being rarely observed.

Elements :	Clinodiagonal	a = 0.502
	Orthodiagonal	b = 1.
	Vertical axis	c = 0.559
	Angle of axes XZ	= 64° 29½′

Angles between Normals.

	Observed.	Calculated.
010 and $\bar{1}10$	= 65° 38′	Fundamental angles.
010 " 011	= 63° 14′	Fundamental angles.
011 " $\bar{1}10$	= 57° 35′	Fundamental angles.
$\bar{1}10$ " $\bar{1}\bar{1}0$	= 48° 42′	48° 44′
010 " 021	= 44° 41′	44° 45′
021 " 011	= 18° 33′	18° 29′
011 " $0\bar{1}1$	= 53° 33′	53° 32′
011 " $\bar{1}01$	= 42° 25′	42° 23½′

Since* Dr. F. Becke's results of the determination of the same crystals do not appear to be reconcilable with the above, a comparison is important. The forms *r* (110) *l* ($1\bar{1}0$) when referred to the crystals which I have examined, correspond to {021}, and *o* ($\bar{1}11$), *u* ($\bar{1}\bar{1}1$) would, if present, occur as the prism {120}. Among the many sets of crystals submitted to me I have never observed the prism {120}. The following table shows a few of the angles both actual and hypothetical, assuming that the crystals are monoclinic in form, when compared with Becke's corresponding measurements.

Monoclinic.	Becke.
(010) ∧ (021) = 44° 41′	44° 42′ = *br*
(021) ∧ ($0\bar{2}1$) = 90° 38′	91° 11′ = *rl*
($0\bar{2}1$) ∧ ($0\bar{1}0$) = 44° 41′	44° 13′ = *bl*
(010) ∧ ($\bar{1}20$) = 47° 45⅔′	47° 19′ = *bu*
($\bar{1}20$) ∧ ($\bar{1}\bar{2}0$) = 84° 28⅔′	84° 55′ = *ou*
($\bar{1}\bar{2}0$) ∧ ($0\bar{1}0$) = 47° 45⅔′	48° 10′ = *bo*
(010) ∧ (021) = 44° 41′	44° 27½′ = mean of *br* and *bl*
(010) ∧ (120) = 47° 45⅔′	47° 44½′ = " " *bu* " *bo*

The following measurements, which were obtained from a single crystal, appear to establish conclusively the system of crystallization as monoclinic.

* Sitzungsberichte der kaiser. Akad. der Wissensch., Band lxxxiii. 286–287, Wien, 1881.

Zone [010, 110]

$$(110) \wedge (010) = 65^\circ\ 33'$$
$$(010) \wedge (\bar{1}10) = 65^\circ\ 44'$$
$$(\bar{1}10) \wedge (\bar{1}\bar{1}0) = 48^\circ\ 28'$$
$$(\bar{1}\bar{1}0) \wedge (0\bar{1}0) = 65^\circ\ 52\tfrac{1}{2}'$$
$$(0\bar{1}0) \wedge (1\bar{1}0) = 65^\circ\ 35'$$
$$(1\bar{1}0) \wedge (110) = 48^\circ\ 44'$$
$$359^\circ\ 56\tfrac{1}{2}'$$

Zone [010, 011]

$$\left.\begin{array}{l}(010) \wedge (021) = 44^\circ\ 41' \\ (021) \wedge (011) = 18^\circ\ 30'\end{array}\right\}\ 63^\circ\ 11'$$
$$(011) \wedge (0\bar{1}1) = 54^\circ\ \ 5'$$
$$(0\bar{1}1) \wedge (0\bar{1}0) = 62^\circ\ 56'$$
$$180^\circ\ 12'$$

$$(1\bar{1}0) \wedge (011) = 122^\circ\ 32\tfrac{1}{2}'$$
$$(011) \wedge (\bar{1}10) = 57^\circ\ 18\tfrac{1}{2}'$$
$$179^\circ\ 51'$$
$$(0\bar{1}1) \wedge (\bar{1}\bar{1}0) = 57^\circ\ 2\tfrac{1}{2}'$$

The crystal face $(0\bar{1}1)$ was somewhat imperfect, so that the reflected image was extended in width. Hence, the angles between $(0\bar{1}1)$ and adjacent planes are rendered uncertain, but only by the small value of 7′ or 8′. All the other faces gave exceedingly sharp reflections.

From these considerations upon the system in which tribromacrylic acid crystallizes, it will appear that we have to deal with a question of small differences, and that in consequence of the very prominent monoclinic habit, we are justified in making these crystals monoclinic, and not triclinic, as Becke has determined them.

XI.

CONTRIBUTIONS FROM THE PHYSICAL LABORATORY OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

XV. SIMPLE METHOD FOR CALIBRATING THERMOMETERS.

By Silas W. Holman.

Presented March 8, 1882.

The calibration of a thermometer by most of the methods in ordinary use is a tedious and somewhat difficult operation, and hence often neglected even in important work. For the purpose of supplying a method simple both in observation and computation, and at the same time accurate, the following process is described, which, although involving little that is new, has not, to my knowledge, been used before.

First, however, it is necessary to recall to the attention of observers the fact that, without calibration correction, the readings of a thermometer having a scale of equal linear parts cannot be relied upon within one or more divisions of this scale; and that thermometer makers, knowing this, almost universally space the graduation upon the tube to correspond more or less closely with the shape of the bore, as determined by previous calibration or by comparison with a standard (!) instrument. This practice is much more general than is ordinarily supposed, and has an important bearing upon the accuracy of the work done with such instruments. For the scale thus made is merely approximate, the dividing-engine or other tool being changed only at such intervals as to make the average error less than some specified amount. An inspection of these conditions will show that the calibration of such a tube and scale can be only approximate, except with corrections for the inequalities of the spacing, involving an amount of labor disproportionate to the result attained. The best makers, such as Fastré, Baudin, and others, have produced satisfactory thermometers graduated to equal volumes; but even these are not as reliable as instruments of less cost with a scale of equal linear parts, say of millimetres, supplemented by a calibration by the observer rather than an approximation by the maker.* The best form of tube for almost all work is one backed with white enamel, with an inverted pear-shaped bulb at the upper end of the capillary (a very important feature), and with a scale of equal arbitrary linear parts (0.7 mm. to 1 mm. is a suitable length for estimation of tenths) or of approximate degrees, for convenience, etched or engraved upon it.

Without reviewing here the methods proposed by various writers, it may be said that it has been the general plan to select beforehand upon the scale two points between which to make the calibration, this space being considered the "calibration unit"; the errors of these points being, of course, zero. This plan has led to unnecessary complexity in the resulting methods. Such an assumption is no more requisite in calibration after a scale has been put upon the tube, than in calibrating by the dividing-engine or micrometer before making the scale. It is obvious, therefore, that the selection of these points is wholly arbitrary, and, if used at all, one or both of them may, if desirable, be chosen after the observations with the calibrating thread have been made. The choice should be made with the view of facilitating the work. Hence the use of the observed freezing and boiling-points, upon which some methods are based, is most undesirable.

In the method which will now be given, either one or both of these points may be left to be selected, according to the combined conditions of length of thread employed, shape of the tube, and numerical convenience, after the observations with the thread have been made.

Let it be desired to find the calibration corrections for a given tube. Determinations which will give the errors of every 3 cm. of length will ordinarily be sufficient, but this must depend upon the result sought. Separate a thread of mercury of about that length. The actual length of the thread within two or three millimetres is of no consequence whatever; and hence a suitable thread can be obtained in a very short time.

Set the thread with its lower end at or near the beginning of the graduation: call the reading† of the lower end of the thread l_1,

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* It should be noted that thermometers intended for measurements above about 280°C. almost always contain sufficient air to render the separation of a thread for calibration difficult, if not impossible. The object of the air is that its pressure upon the top of the column may prevent the mercury from entering into ebullition.

† Tenths of a division are supposed to be read by estimation.

and that of the upper end u_1. Move the thread less than 1 mm. and read again, finding thus l_2 and u_2. Move the thread about 1 cm. and read l_3 and u_3. Move less than 1 mm. and read l_4 and u_4. So continue throughout the whole length of the graduation, increasing the number of settings and repeating the whole series in reverse order, if the highest attainable precision is desired. Avoid, as far as convenient, taking readings with an end of the thread apparently just at a line of the scale, as the width of the line, even in the best scales, is a source of considerable error.* If the zero point of the graduation has for any reason been selected as the first of which the error should be assumed zero, the settings may to advantage, though not necessarily, be made to extend each way from this.

Then $u_1 - l_1$, $u_2 - l_2$, &c. will give a series of lengths of the calibrating thread in all parts of the tube. Before reuniting this thread to the rest of the mercury, plot points with abscissas l_1, l_2, &c., and ordinates $u_1 - l_1$, $u_2 - l_2$, &c., the corresponding lengths of thread, and draw a smooth curve through the points thus obtained. This line will give a general idea of the form of the capillary bore; and, should any parts of it show considerable irregularities, the corresponding portions of the tube should be at once re-explored with the thread.

If not already done, the point, A, upon the scale, to be used as the starting or reference point of the computation, should now be selected. In general the extreme ends of the tube are to be avoided, as more likely to have been rendered irregular or rapidly tapering in the process of making or joining on the bulbs. If the zero of the numbering is placed two or three centimetres from the bottom of the tube, it forms a desirable starting-point.

Find upon the curve the ordinate u' corresponding to the abscissa A; then with abscissa $A + u'$ find the corresponding ordinate u''; with abscissa $A + u' + u''$ find the corresponding ordinate u''', thus continuing to the upper limit of the graduation. If A is at a sufficient distance from the lower end of the graduation, find for the point with abscissa $A - w'$ the corresponding ordinate w'; as may be readily done, when necessary, by inspection of the curve, finding the ordinate, which, added to its corresponding abscissa, will give A; then with the abscissa $A - w' - w''$ find the ordinate w'', &c. These points $A - w' - w''$, $A - w'$, A, $A + u'$, $A + u' + u''$, &c., upon the graduation are the points separated by equal volumes of the capillary. When the calibration extends both ways from the zero of graduation,

* Some of the advantages of Neumann's method are offset by this error.

the readings below A should be treated in the same way as those above that point, and this case will therefore not be further considered. Select any one of these as the second point of which the error is to be arbitrarily assumed as zero, and call this B. Then

$$A + u' + u'' + \ldots . + u^{\text{nth}} = B.$$

There are thus n spaces of equal volume between A and B, and these correspond each to $\frac{1}{n}$th of the interval $B - A$. Hence the true reading (which, however, it is not necessary to compute numerically) at the point

A	is	A
$A + u'$	"	$A + \frac{1}{n}(B - A)$
$A + u' + u''$	"	$A + \frac{2}{n}(B - A)$
. . . .		. . . .
B	"	B
$A - w'$	"	$A - \frac{1}{n}(B - A)$
$A - w' - w''$	"	$A - \frac{2}{n}(B - A)$
&c.		&c.

And the error, obtained by subtracting the true readings as given in the right-hand column from the corresponding actual reading given in the left-hand column, at

A	is	O
$A + u'$	"	$A + u' - \{A + \frac{1}{n}(B - A)\} = u' - \frac{1}{n}(B - A)$
$A + u' + u''$	"	$u' + u'' - \frac{2}{n}(B - A)$
. . . .		. . . .
B	"	O
$A - w'$	"	$- w' + \frac{1}{n}(B - A)$
$A - w' - w''$	"	$- w' - w'' + \frac{2}{n}(B - A)$
&c.		&c.

In selecting B it might have been assumed equal to $A + u'$, thus making $n = 1$. This would somewhat simplify the calculation, and would be of equal accuracy, but is objectionable from the fact that in general this volume would differ considerably from the average volume obtained when n has a greater value (always an integer), and the resulting series of errors would assume larger numerical values.

The errors or corrections are, for purposes of interpolation, most conveniently represented graphically by a smooth curve through points with abscissas proportional to the direct readings

$$A - w', A, A + u', A + u' + u'', \&c.,$$

and ordinates to the corresponding corrections.

Should it be necessary to increase the accuracy by a second calibration with a thread of different length, it is only necessary to take one of approximately an integral part of $(B - A)$, and when the final curve of error is drawn, make the error at B equal to zero, distributing the difference at that point proportionally to the scale readings among the errors at the intermediate points: in other words, to shift the axis of the second curve of error so that it shall make the error at B zero. The superposition of a second curve of error deduced from the same series of observations as the first, but using another starting-point, A' differing from A by a suitable fraction of the length of the thread used, will somewhat increase the accuracy of the result by rendering interpolation more certain, but neither of these procedures is requisite except where a very detailed study of the instrument is to be made.

This method requires for each calibration the use of but a single thread. The computation is simple, and involves a minimum of approximation. Errors of observation are largely eliminated by the number of settings made in all parts of the tube, and by the inspection of the curve of lengths, both of which operations tend in an unusual degree to detect any mistakes or minor irregularities of the capillary. It avoids the common requirement of setting the thread exactly at certain definite points in the tube, or any approximate correction for slight errors in such setting, two sources of considerable error and inconvenience, especially when the thread must be set near or under a line of the graduation. And, lastly, the total time of calibration for a result of given accuracy is reduced to one half or one third of that required by Neumann's method, the quickest and most satisfactory with which I am acquainted, except that given by Pickering. The latter, described with some slight inaccuracies at the reference noted below, is a neat application of the graphical method, and the curve of lengths of thread adopted in the method which I have described is identical with the corresponding one given by Professor Pickering, while the whole process is fully one third shorter and somewhat more accurate. From a series of calibrations executed upon the same thermometer (one with a millimetre scale by Baudin of Paris), using a variety of methods, I have obtained slightly more concordant results with the proposed method than with Neumann's or Pickering's, all three possessing, however, nearly the same degree of precision, and decidedly better results with these than with any of the other existing simple methods.

Considerable aid in eliminating errors of parallax in such work is sometimes found by looking down upon the horizontal thermometer through a vertical tube having a small hole at each end. One of the cheap French microscopes with its lenses removed, and inverted in its stand, answers this purpose well. With such a device two calibrations of the above described thermometer with threads of 3 cm. and 5 cm. respectively, each with only one series of observations, and requiring not more than one hour and a half each for completion, gave results whose average difference from each other at nine points was 0.04 mm., and the arithmetical sum of the extreme differences was 0.12 mm., a result of sufficient accuracy for any class of work of which such an instrument is capable.

For brief descriptions of methods of separating threads of mercury for calibration, reference may be made to the paper by Russell and the text-book by Pickering noted below. These processes are in general use, and are safe and convenient.

Massachusetts Institute of Technology,
Boston, Feb. 1st, 1882.

References upon Calibration of Closed Thermometer Tubes.

Bessel. Pogg. Ann., vi. 287 (1826).
Rudberg. " " ix. 535, 566.
" " xxxvii. 376 (1836).
" " xl. 39, 562 (1837).
Kohlrausch. Physical measurements, p. 59 [Engl. Transl.].
Pickering. Physical Manipulation, ii. 75 (1876).
Thiesen. (Neumann's Method.) Carl's Rep., xv. 285 (1879).
Russell. (" ") [Transl. from Thiesen]. Amer. Jour. Sci., xxi. 373 (1881).
Marek. Carl's Repertorium, xv. 300 (1879). [Solution by least squares.]
Von Oettingen. Inaug. Diss. (Dorpat, 1865).
[This I have been unable to obtain. S.W.H.]

XII.

CONTRIBUTIONS TO NORTH AMERICAN BOTANY.

By Asa Gray.

Presented February 8, 1882.

I. *Studies of Aster and Solidago in the Older Herbaria.*

Aster and Solidago in North America, like *Hieracium* in Europe, are among the larger and are doubtless the most intractable genera of the great order to which they belong. In these two genera, along with much uncertainty in the limitation of the species as they occur in nature, there is an added difficulty growing out of the fact that many of the earlier ones were founded upon cultivated plants, some of which had already been long in the gardens, where they have undergone such changes that it has not been easy, and in several cases not yet possible, to identify them with wild originals. Late flowering *Compositæ*, and Asters especially, are apt to alter their appearance under cultivation in European gardens. For some the season of growth is not long enough to assure normal and complete development, and upon many the difference in climate and exposure seems to tell in unusual measure upon the ramification, inflorescence, and involucral bracts, which afford principal and comparatively stable characters to the species as we find them in their native haunts. I am not very confident of the success of my prolonged endeavors to put these genera into proper order and to fix the nomenclature of the older species; and in certain groups absolute or practical definition of the species by written characters or descriptions is beyond my powers. But no one has ever seen so many of the type-specimens of the species as I have, nor given more time to the systematic study of these genera. The following notes should therefore be of use.

It is noticeable that the herbarium of Nees von Esenbeck for *Aster* is not referred to. *I cannot ascertain what has become of it.* But the types of several of his species, or specimens named by him, have been met with in other herbaria, especially in that of Lindley and that of Schultz, Bip., the latter now a part of the large collection of Dr. Cosson. As to Asters, I do not here attempt anything beyond a report of the main results of the study of certain principal herbaria; and I leave the high northern and far western species out of the present view.

Besides general acknowledgments to the curators and botanists who have in all cases most obligingly facilitated my researches, special thanks are due to Professor Lawson, of Oxford, and Professor Eichler, of Berlin, who kindly sent to Kew, for leisurely examination and comparison, one the Asters and Solidagoes of the herbaria of Morison and of Sherard, the other those of Willdenow.

1. *Notes on the North American Asters in the Older Herbaria.*

I. *Species of Linnæus.*

A. Sibiricus. Founded on Gmelin's Siberian plant. Two specimens in the Linnæan herbarium: they belong to a robust form of the species which is represented in North America by the *A. montanus* of Richardson.

A. divaricatus. Founded, as to the plant in the herbarium, on the upper part of a specimen of *A. corymbosus*, Ait., wanting the cordate petioled leaves, and with open inflorescence unusually foliolose. But the synonyms, both of Gronovius and of Plukenet, relate to *A. infirmus*, Michx., *A. cornifolius*, Muhl. The Linnæan name in this case should subside.

A. dumosus. Herbarium specimen of the very early cultivated plant, and still in cultivation as a low and far more densely *bushy* plant than we find in the wild state. The figure in Hermann's Paradisus referred to by Linnæus answers well to the wild species; that of Plukenet more resembles the early cultivated form.

A. tenuifolius. This is founded upon an indigenous specimen in the herbarium, which is well described. As I have several years ago recorded, it is Nuttall's *A. flexuosus*, which must give place to the Linnæan name. The cited figure of Plukenet (which does not well correspond with Plukenet's phrase) belongs *probably* to *A. polyphyllus*, Willd.

A. linariifolius. Seemingly an indigenous specimen of this well-known species.

A. RIGIDUS. Not in the herbarium; founded wholly on Gronovius, Fl. Virg.; and Clayton's plant is identical with the preceding species.

A. LINIFOLIUS and A. HYSSOPIFOLIUS, Mant. 114, both belonging to *Galatella*, an Old World group, were erroneously referred to North America (where nothing of the kind has been detected), and are to all appearance mere varieties of *A. acris*, L. *A. linifolius* originated in Hort. Cliff. No. 15, and there is a specimen in Clifford's herbarium. The synonym of Morison relates to something else, perhaps to *A. tenuifolius*, L.; the plant of Gronov. Fl. Virg. referred to is *A. tenuifolius*, L. So that the name *linifolius* completely subsides, at least as regards the American flora.

A. CONCOLOR. Two specimens, one from Kalm ("K"), and perhaps the other also; probably collected in New Jersey.

A. UNDULATUS. Specimen from Kalm; the form with some cinereous pubescence, extending even to the involucral bracts; lower part of the stem wanting; pretty clearly the *A. diversifolius* of Michaux, and not the *A. patens*. The character and good figure cited from Hermann's Paradisus are a part of the foundation of the species; from his phrase, "foliis undulatis," Linnæus took the specific name; and the figure is characteristic.

A. NOVÆ-ANGLIÆ. The species is wholly clear, and comes down, with its name, from Tournefort and Hermann. But in his herbarium Linnæus had somehow confounded it with *A. grandiflorus*, and Smith corrected the mistake.

A. ERICOIDES. In the second edition of the Species Plantarum this is brought next to *A. dumosus*. The specimen in the herbarium from the Upsal Garden is an attenuated floriferous state of the received species. But the Dillenian plant from which Linnæus drew the specific name, and also the plant of Clayton, the character of which, by Gronovius, Linnæus copied as that of his *A. ericoides*, are *A. multiflorus*, Ait. Solander, therefore, ought to have continued the name of *ericoides* for the Dillenian and Gronovian plant, unless he could ascertain that the specimen in the Upsal Garden was in the herbarium as early as the year 1753. That cannot be done. But the two species must now continue as named and characterized in Ait. Hort. Kew.

A. CORDIFOLIUS. The species largely rests on the plants of Cornuti and of Morison, both well figured, and the latter identified in his herbarium. There is a specimen in the Linnæan herbarium, unnamed by Linnæus, however; but Smith has written "cordifolius verus, fide Cornuti." Kalm's specimen, ticketed *cordifolius* by Linnæus, is *A. corymbosus*, Ait.; so that Linnæus confounded the two, and Solander first distinguished them.

A. PUNICEUS. Specimen from Kalm; unequivocal, as also is the figure and character of Hermann, from the "puniceis caulibus" of which Linnæus drew the specific name.

A. ANNUUS. The *Erigeron annuus*.

A. VERNUS. The *Erigeron vernus*, not in the herbarium of Linnæus, but taken wholly from Gronov. Fl. Virg.

A. LÆVIS. Credited to Kalm and described wholly from his specimen; it is the well-known species, in the form known as *A. rubricaulis*, Lam., and *A. cyaneus*, Hoffm.

A. MUTABILIS. No trace of it in the Linnæan herbarium, although indicated as being there by the underscoring of the number in Linnæus's copy of the Spec. Pl. ed. 1. The species must be discarded as a complex one, the adduced plants being incongruous, and it being now impossible to know what materials were under observation. The original character, in ed. 1, 875, does not agree with "Pluk. Alm. 56, t. 326, p. 1," which is not to be found in Plukenet's herbarium, and which may be *A. dumosus* or a *Galatella*. There Linnæus compares it with a species, *A. serotinus*, which he never published nor preserved in his herbarium. Finally, in the second edition of the Spec. Pl., he reconstructed the character in a manner incompatible with the former one, introduced before the Plukenetian synonym one from Herm. Hort. Lugd. t. 67, which (on the authority of the contemporary herbaria of Royen and of Sherard) proves to be *A. lævis*, L., and changed the comparison to one with *A. Tradescanti*. The new character agrees no better with either figure than these do with each other. The *A. mutabilis* of Ait. Hort. Kew. has an earlier and good name in *A. lævigatus*, Lam.

A. TRADESCANTI. Likewise a compound, of which the elements have been variously employed; but the name may be kept up by going back to its origin, that is, to the *Aster Virginianus ramosissimus serotinus, parvis floribus albis Tradescanti*, Morison, Hist. iii. 121. This, as found in Morison's herbarium and in Sherard's, is the smallest flowered paniculate species, the *A. fragilis* Willd. (not Torr. and Gray), *A. leucanthemos*, Desf., *A. artemisiæflorus*, Poir., *A. parviflorus*, Nees., and a part of *A. tenuifolius*, Torr. and Gray. It is still continued in European cultivation, here and there becoming naturalized. This, then, is *A. Tradescanti* of Linnæus, Spec. Pl., as to syn. Moris., which gave the name, and in part as to Hort. Cliff. That is, of the two specimens in Cliffort's herbarium, one belongs to Morison's species; the other, which was taken up in Torr. and Gray's Flora as the foundation of the species, is the racemose *A. vimineus*, Lam., *A. Tradescanti fragilis*, Torr. and Gray. But I now understand that Cliffort's herbarium is really no authority for Linnæan species. The specimen preserved in the Linnæan herbarium is from the Upsal Garden, of unknown date; but as "Hort. Ups. 262" is cited under the species, it was probably in hand when the character was drawn up. It belongs to a related species with larger heads, of which the next oldest name is *A. paniculatus*, Lam. This name should be employed for the larger-flowered, and *A. Tradescanti* for Tradescant's small-flowered species.

A. Novi-Belgii. This is really founded wholly on the *A. Novæ-Belgiæ latifolius umbellatus floribus dilute violaceis*, Herm. Hort. Lugd. 67 and (tab.) 69, which, from early specimens, can be fairly identified with a polymorphous species still common in the gardens, in a variety of forms and under several names, *A. floribundus*, *serotinus*, *adulterinus*, *eminens*, *præaltus*, &c., all of them apparently derived from a common and most variable species of the Atlantic States near the coast, which has been by me referred (not correctly) to *A. longifolius*, Lam. But the indigenous specimen so named in the Linnæan herbarium, from Kalm, is clearly *A. puniceus*, L., and one from the Upsal Garden is *A. paniculatus*, Lam., or near it.

A. tardiflorus, founded entirely on specimens cultivated in the Upsal Garden, is confidently identified with a low form of *A. patulus*, Lam., a northern species, not rare in cultivation, but little known by indigenous specimens. This low form is most like *A. prenanthoides*. The species dates only from the second edition of the Species Plantarum; it is said to have been cultivated for eighteen years before it flowered, and then late in the season. But the cultivated *Aster* which matches the Linnæan specimens (of two sterile stems with lower leaves, and a stronger flowering one destitute of them) blossoms unusually early. So it is doubtful whether the Linnæan name (which has commonly been applied to a form of *A. Novi-Belgii*) ought to be kept up.

A. grandiflorus. Not in the Linnæan herbarium; but this well-marked species is founded on the excellent figures of Martyn and of Dillenius, and on Gronov. Fl. Virg. Clayton's plant came directly from the rather limited district which this species inhabits.

A. MISER. A name to be suppressed. It was wholly characterized, not upon any plant, but upon the figure of "*A. ericoides Meliloti agrariæ umbone*," Dill. Elth. 40, t. 35, fig. 39. Even the description by Dillenius must have been made mainly from the plate, for it is a caricature or exaggeration of the specimen (completely identified) in the Sherardian herbarium, said to be raised from New England seeds. It is either a sparsely-flowered state of *A. vimineus*, Lam., or a subracemose form of *A. dumosus*, L. The umbonate or much protuberant disk of the capitulum in the plate is quite fictitious (as is also the "*caulis crassus*"), at least there is no trace of it in the specimen which evidently served for the figure. Yet this umbo and the thick stem give the sole diagnosis of the Linnæan species.

A. MACROPHYLLUS is the well-known species.

A few specimens which had not been named or not taken up by Linnæus may be passed by. Linnæus did not well know his species of *Aster* and of *Solidago*. Consequently, while retaining most of his species, it is necessary to suppress three or four of his names.

II. *Species founded by Lamarck*, 1783, *in Dict.* i. 301–308.

The identifications gathered at Paris in Hort. Mus. Par., the General Herbarium, and those of Tournefort and of Jussieu. The proper herbarium of Lamarck at Rostock I have not been able to consult. But distinct traces of all the species, with one exception, have been found at Paris.

A. AMPLEXICAULIS. A form of *A. Novæ-Angliæ*, L.; but the synonym from herb. Tournefort is of *A. puniceus*, L.

A. AMYGDALINUS. The common northern form of *A. umbellatus*, Mill. Dict. 1759, the older name.

A. RUBRICAULIS. The *A. lævis*, L.

A. AMŒNUS. The *A. puniceus*, L.

A. PANICULATUS. A common and multiform northern species, the *A. Tradescanti*, L., as to herb. and Hort. Ups. (but not of Morison), comprising *A. tenuifolius* and *A. simplex* of Torr. and Gray, Flora, mainly, excl. syn. Name changed by Nees to *A. Lamarckianus*, but to be restored, being older than the homonym of Aiton.

A. SALICIFOLIUS. Not found, nor was the "*Virga aurea Canadensis elatior, salicis minoris folio*, Nees," identified in the herbarium of Jussieu. I was informed by Professor Roeper that no specimen was to be found in the herbarium of Lamarck. From the character, one may perhaps assume its identity with the later homonym of Ait. Hort. Kew.

A. VIMINEUS. The *A. Tradescanti* and var. *fragilis* of Torr. and Gray, Flora. A name to be employed.

A. LONGIFOLIUS. A form of the *A. junceus*, Ait., and *A. salicifolius*, Richardson; a northern species, for which this, the oldest name, must be employed.

A. LÆVIGATUS. The *A. mutabilis* of Aiton, common in European gardens under the name of *A. brumalis*, Nees. It was well compared by Lamarck with *A. lævis*, and as differing by its more simple or not imbricated involucre. Unequivocal indigenous specimens are hardly known; they are to be sought in Lower Canada and Nova Scotia.

A. HISPIDUS. By the character clearly *A. puniceus*, L., to which it has been referred.

A. PATULUS. The species still cultivated under this name, native of Canada, &c., a low form of which is *A. tardiflorus*, L.

A. MISER, Lam. (not L.), is the *A. purpuratus* of Nees, *A. virgatus*, Ell.

III. *Species of Walter, Flora Caroliniana*, 1788.

A. CAROLINIANUS. } Well-known species, taken up by Michaux.
A. SQUARROSUS. }

A. CILIATUS is quite unknown.

IV. *Species founded (by Solander) in Aiton, Hortus Kewensis*, 1789.

A. NEMORALIS. The well-known species.

A. UMBELLATUS. Credited to Mill. Dict. (1759), therefore much earlier than *A. amygdalinus*, Lam. The indigenous specimen from Nova Scotia is of a broad-leaved form, while those of Hort. Chelsea (Miller's) and of Hort. Kew. are narrower-leaved.

A. PALUDOSUS. Type of the section *Heleastrum*.

A. PATENS. Specimens from Miller, and from New York, Anderson. But the specimen collected by Bartram in East Florida is *A. Carolinianus*.

A. FOLIOLOSUS. A state of *A. vimineus*, Lam., verging to *A. dumosus*, L. The plant of Dill. Elth., on the figure of which Linnæus founded *A. miser* (*vide supra*), is referred here. Solander must have seen the specimen in the Sherardian herbarium; otherwise he could hardly have made it out.

A. ERICOIDES. Here the species originates, as distinguished from the next. The specimens are well marked, and bear also the name of *A. lucidus*, Solander.

A. MULTIFLORUS. The *A. ericoides dumosus* of Dill. Elth; and, being the Gronovian plant also, it would more properly have retained the Linnæan name, as already stated.

A. SALICIFOLIUS. A floriferous branch or summit of the plant which is named *A. carneus* in Torr. and Gray, Fl. N. Am., and which may also be *A. salicifolius*, Lam. The specimen is of "Hort. Kew. 1781." Another specimen, ticketed as a variety, is different, perhaps *A. polyphyllus*, Willd.

A. ÆSTIVUS. Two specimens on one sheet: Hort. Lee and Hort. Kew.; the species still in cultivation; not that of Torrey and Gray's Flora, but one more nearly related to *A. paniculatus*, Lam., apparently indigenous only in British America.

A. JUNCEUS. Apparently the *A. longifolius*, Lam., at least the indigenous plant from Nova Scotia; but the specimen from "Hort. Kew. 1771," on which the species may be said to be founded, seems to be a narrow-leaved form of *A. paniculatus*, Lam.

A. PENDULUS. A form of the next, with slender divergent branches; the *A. miser*, var. *diffusus*, Torr. and Gray.

A. DIFFUSUS. "Hort. Collinson, 1762, Hort. Kew. 1777, Hort. Lee, 1781." All forms of *A. miser*, var. *diffusus*, Torr. and Gray: and this common and well-marked species may take the name of *diffusus* rather than either the preceding or the following name.

A. DIVERGENS. "Hort. Kew. 1777," the specimen nearly destroyed, and "Nova Scotia, prope Halifax, Halbgren, 1779." Clearly of the preceding species.

A. MISER. "Hort. Kew. 1777," of course not the Linnæan plant; appears from the very small heads to be the Morisonian *A. Tradescanti*.

A. MUTABILIS. Specimens from "Hort. Kew. 1777, Hort. Collinson, Hort. Jacquin." Being all of the same species, this might be taken in place of the undeterminable Linnæan *mutabilis*; but it is the earlier published *A. lævigatus*, Lam., which, therefore, is the name to be adopted.

A. NOVI-BELGII. Specimens of various Asters, throwing no light upon the Linnæan species.

A. PANICULATUS. Name pre-occupied by Lamarck; the specimen (not a good one) is of "Hort. Gordon, e sem. Labrador," and is pretty clearly the same as *A. Lindleyanus*, Torr. and Gray, which name may be continued, although *A. ciliolatus*, Lindley, is apparently only a small form of it.

A. SPECTABILIS. The well-marked species, cultivated at Kew Gardens in 1777.

A. RADULA. The recognized species, originally from Nova Scotia, near Halifax.

A. BLANDUS, Pursh, Fl. ii. 555, is a species of Solander's, in the Banksian herbarium, described and published by Pursh from too scanty material, a specimen collected on Bisque Island in the St. Lawrence by Halbgren. And Solander indicates as a variety of this a specimen from John Bartram. If not reduced and nearly smooth forms of *A. puniceus*, both must belong to the *A. tardiflorus*, L., which see.

V. *Species originating in Michaux, Flora Boreali-Americana*, 1803.

A. SOLIDAGINEUS. The *Sericocarpus solidagineus* of Nees.

A. MARILANDICUS. *Sericocarpus conyzoides*, Nees.

A. TORTIFOLIUS. *Sericocarpus tortifolius*, Nees.

A. INFIRMUS. Somewhat earlier published than *A. cornifolius*, Muhl. in Willd. Spec., for the volume containing the latter cites Michaux. The habitat, "a Canada ad Carolinam," is erroneous as respects Canada: the stations assigned in Michaux's Flora are not rarely incorrect in a similar way. As is well known, this is *A. divaricatus* of Linnæus as regards the synonymy, but not of his herbarium, nor of the specific character. The present name is to be adopted.

A. ACUMINATUS. The well-known species. It appears, from the herbarium of Jussieu, that this is the *A. divaricatus* of Lamarck, but not of Linnæus.

A. UNIFLORUS. A small and simple-stemmed form of the *A. nemoralis* of Aiton.

A. SUBULATUS. A mixture of the small-rayed and conyzoid coast species and of the nearly-related larger-rayed one (*A. divaricatus*, Torr. and Gray, Fl.), but in the proper herbarium mainly the former, to which only the character applies, especially the "ligulis radii minutis." This name to be employed, for it proves that no part of *A. linifolius*, L., belongs here.

A. ARGENTEUS. *A. sericeus*, Vent., slightly earlier published.

A. CORIDIFOLIUS. A marked variety of *A. dumosus*, L., of the pine-barren district of the Southern Atlantic States.

A. SPARSIFLORUS. A slender form of *A. dumosus*, L.

A. SURCULOSUS. The recognized species, from North Carolina.

A. DIVERSIFOLIUS. Same as *A. undulauts* of Linnæus and of most authors.

A. VILLOSUS. *A. ericoides*, var. *villosus*, Torr. and Gray.

A. AMPLEXICAULIS. *A. patens*, Ait.; and there is an earlier *A. amplexicaulis*, Lam.

A. BIFLORUS. A small northern variety of *A. radula*, Ait.

Nearly all the Michauxian species had already been well determined.

VI. *Species originating in Hoffmann, Phytographische Blätter*, 1803.

A. CYANEUS. Clearly *A. lævis*, L.

A. THYRSIFLORUS. The figure and detailed description point to the *A. Novi-Belgii*. The plant in cultivation under the name twenty to forty years ago, and preserved in herbaria, has smaller and narrower leaves.

VII. *Species originating in Willdenow, Species Plantarum*, iii. *part* 3, *published in* 1803. [Later than Michaux, whose species are mentioned, and farther on in the book the Flora is cited by volume and page.]

A. PILOSUS. The *A. villosus* of Michaux, whose name is given as a synonym, and whose specimen was described.

A. CILIATUS, Muhl. in litt. Is *A. multiflorus*, Ait.

A. SPURIUS. *A. Novæ-Angliæ*, a cultivated form.

A. PHLOGIFOLIUS, Muhl. The recognized plant, from Muhlenberg, *A. patens*, var. *phlogifolius*.

A. SAGITTIFOLIUS, "Wedermeyer." The specimens on fol. 1, 2, 3, represent the species in the herbarium; that of Torrey and Gray's Flora.

A. HUMILIS. The indigenous specimen from Muhlenberg is a low and broad-leaved form of *A. umbellatus*, Ait., *i. e.* the *Diplopappus amygdalinus* of Torr. and Gray's Flora. The cultivated specimen, answering to the figure in Hort. Berol. t. 67, is *A. infirmus*, Michx. The character appears to have been drawn from the former.

A. CORNIFOLIUS, Muhl. Same as the *A. infirmus*, Michx., and as the *A. humilis* figured in the Hortus Berolinensis.

A. ELEGANS. Described from a cultivated plant of unknown origin; the specimen in the herbarium is *A. spectabilis*, Ait., under which De Candolle cites the species, but also under *A. squarrulosus.*

A. CONYZOIDES. *Sericocarpus conyzoides*, Nees.

A. VERSICOLOR. Name to be adopted for the species most closely related to *A. lævis*, L. It is represented in the herbarium by fol. 1, 2, and perhaps 3, which has no flowers. Fol. 4 is of *A. Carolinianus*, and fol. 5, of some other species, possibly *A. salignus.*

A. LÆVIGATUS. A mixture in the herbarium. Fol. 1 is either *A. lævis* or *A. versicolor;* fol. 2 is a fragment of *A. prenanthoides*, Muhl.; fol. 3, of *A. puniceus;* fol. 4 is wholly doubtful; and fol. 5 is of *A. lævigatus*, Lam., a far older homonym.

A. PRENANTHOIDES, Muhl. The well-marked species, from Muhlenberg.

A. AMPLEXICAULIS, Muhl. Not the homonym of Lamarck, nor of Michaux. This is *A. lævis*, L.

A. RECURVATUS, Willd. The specimen, "Hort. Berol.," seems to be *A. paniculatus*, Lam., or near it; but something else would appear to be described, perhaps *A. diffusus*, Ait., surely not *A. thyrsiflorus*, Hoffm., to which De Candolle refers it in part, for the corolla is said to be no larger than in *A. Tradescanti.*

A. FLORIBUNDUS. Plant of the gardens, apparently *A. Novi-Belgii.*

A. SEROTINUS. Apparently either *A. lævigatus*, Lam., or a form of *A. Novi-Belgii.*

A. LANCEOLATUS. Seemingly the *A. paniculatus*, Lam.

A. DRACUNCULOIDES. Cultivated specimens: fol. 1, 2, are of *A. paniculatus*, Lam.; fol. 3 of same with smaller heads, verging to the Morisonian *A. Tradescanti.*

A. FRAGILIS. The Morisonian *A. Tradescanti*, not the *A. Tradescanti*, var. *fragilis*, Torr. and Gray.

A few notes are added upon the representatives of some earlier species in the Willdenovian herbarium.

A. NEMORALIS. Two sheets; not Aiton's plant, but a *Galatella* of the Old World; and to this the character evidently belongs, being the same as the

A. HYSSOPIFOLIUS. The "Am. Bor." is a continuation of an original mistake. Same of A. LINIFOLIUS.

A. SOLIDAGINOIDES. Michaux's *A. solidagineus*, with a Greek instead of the original Latin termination.

A. FOLIOLOSUS. Fol. 4 is *A. vimineus*, Lam., therefore Aiton's plant or near it; fol. 1 is *A. salicifolius*, Ait., "A. obliquus, Nees;" fol. 2, 3, *A. ericoides*, L. and Ait.

A. TENUIFOLIUS. Of course not the Linnæan plant; but at least four of the eight sheets belong to *A. ericoides;* the others are of various species.

A. SALICIFOLIUS. Apparently *A. æstivus*, Ait., which is represented by cultivated specimens resembling the original in the Banksian herbarium.

A. PANICULATUS is *A. cordifolius*, L. Intended, of course, for the Ait. Hort. Kew. species.

A. CORDIFOLIUS. The specimen from Muhlenberg is of *A. sagittifolius.*

A. SALIGNUS, the name changed from *A. salicifolius*, Scholler; the species referred to Europe (Germany and Hungary), where it probably is indigenous, or at least has long been domiciled.

A. MUTABILIS. Fol. 1, 2 are apparently the same as *A. versicolor;* fol. 3 is nearer *A. lævigatus*, Lam.

A. VIMINEUS. Not of Lam., but the *A. miser*, Lam., that is, *A. purpuratus*, Nees, and *A. virgatus*, Ell.

A. TRADESCANTI. Fol. 1 is of the Morisonian plant; while fol. 5 is *A. patulus*, Lam.

A. SPECTABILIS. Not the Aitonian species, but some long-cultivated one, of the *Novi-Belgii* sort.

A. TARDIFLORUS. Same as the *A. adulterinus*, Willd. Enum., and Lindl. Bot. Reg., the *A. Novi-Belgii* of Hort. Cliff., &c.

A. JUNCEUS. Apparently same as *A. æstivus*, Ait.

A. MISER.
A. DIVERGENS.
A. DIFFUSUS.
A. PENDULUS.
} All belong to the polymorphous species for which the name of *A. diffusus* is preferred, with some mixture of *A. dumosus* L.

VIII. *Species originating in Willdenow, Enumeratio Plantarum Hort. Reg. Bot. Berolinensis*, 1809.

A. SPARSIFLORUS. Michaux's species taken up and described; is *A. dumosus*, a large-leaved form.

A. ADULTERINUS. *A. Novi-Belgii*, answering to the specimens of the plant cultivated in early times, as preserved in herb. Morison and herb. Cliffort.

A. CONCINNUS. Apparently a good species, with small leaves and heads, but still obscure as a wild plant.

A. BELLIDIFLORUS. Apparently derived from *A. paniculatus*, Lam.

A. EMINENS. Apparently a state of *A. salicifolius*. Ait.

A. LAXUS. Probably a form of *A. æstivus*, Ait.

A. SIMPLEX. Appears to be referable to *A. salignus* of Willdenow, which, although related to *A. paniculatus*, Lam., is attributed to Europe.

A. POLYPHYLLUS. A well-marked species, related to *A. ericoides*, but much larger in all its parts; for which I know no earlier name. It is the *A. tenuifolius* of Nees, in part, and of De Candolle. It is a late-flowering species, showy in cultivation, and is little known by indigenous specimens.

In the Supplement to the above, edited by Schlechtendal (the father), 1813, after the death of Willdenow, the two following Willdenowian species originate.

A. PALLENS. A form of *A. patulus*, Lam.

A. PRÆCOX. Ambiguous; probably a form of the preceding.

IX. *Species, or rather Names originating in Poiret, Dict. Suppl.* i. 1810.

A. PRÆALTUS. A change of the name merely of the *A. salicifolius*, Ait. Hort. Kew.

A. PENNSYLVANICUS. Change of name of *A. amplexicaulis*, Muhl. in Willd., that is, *A. lævis*, L.

A. ARTEMISIÆFLORUS. Change of name of *A. dracunculoides*, Willd., but from the character should be *A. Tradescanti*, L., the plant of Morison.

A. STRICTUS. No original seen; probably founded on *A. salignus* of Willdenow.

X. *Species originating in Pursh, Flora Americæ Septentrionalis*, 1814.

A. LEDIFOLIUS. *A. nemoralis*, Ait., with changed name.

A. GRAMINIFOLIUS. Solander's, taken up from herb. Banks; the *Erigeron hyssopifolius*, Michx.

A. CANESCENS. Bradbury's plant, of the *Machæranthera* (*Dieteria*, Nutt.) section.

A. RETICULATUS. The plant which was subsequently named *A. obovatus* by Elliott.

A. BLANDUS. Taken up from Solander in herb. Banks., already noted under Ait. Hort. Kew., at the close.

A. PEREGRINUS. Solander's species in herb. Banks., near to *A. salsuginosus*, Richardson, if not a pubescent form of it.

A. STRICTUS (not of Poiret). A reduced and boreal form of *A. radula*, Ait.; same as *A. biflorus*, Michx.

XI. *Species of the Atlantic United States originating in De Candolle, Prodr.* v. 1836.

A. PATENTISSIMUS, Lindley, in DC., is a form of *A. patens*, Ait., with long branches.

A. AURITUS, Lindley, in DC., is *A. patens*, var. *phlogifolius*.

A. UROPHYLLUS. } Also of Lindley; may both be referred to *A.*
A. HIRTELLUS. } *sagittifolius*, Willd.

A. DRUMMONDII, Lindley. A recognized heterophyllous species of the Mississippi Valley, but ambiguous between *A. sagittifolius* and *A. undulatus*.

A. CILIOLATUS, Lindley. A reduced form of *A. paniculatus*, Ait., that is *A. Lindleyanus*, Torr. and Gray.

A. CÆRULESCENS. Species to be admitted, yet has seemed to pass into *A. salicifolius*, Ait.

A. MULTICEPS, Lindley. Only the *A. oblongifolius*, Nutt., from St. Louis.

A. SUBASPER, Lindley. *A. salicifolius*, Ait., var. *subasper*.

A. HEBECLADUS. } Texan forms of the polymorphous *A. multi-*
A. SCOPARIUS. } *florus*, Ait.

A. HIRSUTICAULIS, Lindley. A narrow-leaved and hairy variety of *A. diffusus*, Ait.

A. STENOPHYLLUS, Lindley. Narrow-leaved form of *A. salicifolius*, Ait.; or the specimen sent to Nees may be the nearly related *A. paniculatus*, Lam.

A. BIFRONS, Lindley. *A. diffusus*, Ait., var. *bifrons*.

A. MICROPHYLLUS, Torr. in Lindley, adn. This is *A. adnatus*, Nutt., earlier published.

A. AZUREUS, Lindley. A well-recognized heterophyllous species.

A. RETROFLEXUS, Lindley. Apparently same as *A. thyrsiflorus*, Hoffm.

A. TURBINELLUS, Lindley. A well-recognized and very distinct species.

The species of the high northern and of the western portions of North America, of which several originate in De Candolle's Prodromus, are not here considered.

2. *Determination of the Species of Solidago.*

I. *Species of Linnæus, as represented in the Linnæan Herbarium and from the earlier sources.*

S. SEMPERVIRENS. An undeveloped specimen of the sea-side species of Atlantic North America. All the synonyms cited in the Species Plantarum appear to belong here; that of Plukenet has been verified.

S. CANADENSIS. Two sheets pinned together: one is a minutely pubescent form of the received species; the other, from Kalm, belongs to *S. rugosa*, Mill., viz. to the plant which has long passed for *S. altissima*. The syn. Pluk. Alm. t. 236, fig. 1, which may have suggested the specific name, is to be excluded.

S. ALTISSIMA. The true original of the Linnæan species is the "Virga aurea altissima serotina, panicula speciosa patula, Mart. Cent. 14, t. 14," *i. e.* Martyn's Hist. Pl. 1728, fol., represented by an excellent plate, clearly representing a large form of *S. Canadensis*, to which Linnæus declares it is very similar. He distinguishes it by "foliis enerviis subintegerrimis;" the last word was changed in the second edition to "serratis." It is a form with thicker and more obscurely triple-nerved leaves than the ordinary *S. Canadensis*. The specimens in the herbarium are confounded, apparently from the first, also by attempted rectifications by Smith. A sheet ticketed by Linnæus "*altissima*," is noted, apparently by Smith's hand, as "*S. Canadensis*," but it probably is not. Another sheet holds specimens numbered 1, 2, 3: the first of these is a panicle of *S. nemoralis*, the second is a branch of *S. bicolor*, the third belongs to *S. odora*. A specimen ticketed "*serotina*" by Linnæus, and by Smith "*altissima*," is the species which has so long passed as *S. altissima*, viz. *S. rugosa*, Mill. The Dillenian figures appended by Linnæus as "*plantas vix genuinas*" belong to the latter species, as the plates themselves show, and the originals in the Sherardian herbarium confirm. These have been wrongly taken as the type of *S. altissima*, which, however, must now be reduced to a synonym of *S. Canadensis*, while the species of Dill. Elth., in all three plates, may assume the old name of *S. rugosa*, Mill., which is much more appropriate than *altissima* for a plant which is seldom tall. The other Solidago, "Virga aurea Marilandica," &c., of Martyn, t. 13, I cannot identify from the figure. It may be the var. *procera* or var. *scabra* of *Canadensis*, but the heads seem much too large.

S. BICOLOR. This species, published in the Mantissa, is in the herbarium under the name of *S. discolor*. Two other sheets are fastened together, both of specimens from Kalm. One of them, ticketed "K. 77, radio albo," and "*bicolor*" in the hand of Linnæus, is not of that species, but seems to be a form of *S. rugosa*. The other, marked only "K.," judging from the character and other indications, must be the original of

S. LATERIFLORA; otherwise that is not in the herbarium. It is a familiar form of the *Aster miser*, var. *diffusus*, Torr. and Gray, Fl., that is, of *A. diffusus*, Ait.

S. LANCEOLATA, also of the Mantissa, is in the herbarium from Kalm, "30," with another specimen, doubtless the original from Royen.

S. MEXICANA. The "Virga aurea limonii folio," &c., of Tournefort, an obtuse-leaved form of *S. sempervirens*, L., which is the name to be adopted. Came in all probability from the temperate North American coast, not from Mexico.

S. CÆSIA. Not in the herbarium under this name. The species was founded on the "Virga aurea Marilandica cæsia glabra" of Dill. Elth. 414, t. 307, f. 395, which, as the plate shows and the original at Oxford proves, is the well-known *S. cæsia*.

S. FLEXICAULIS. The specimen is *S. cæsia*, with which, however, the character "foliis ovatis" and the figures cited from Plukenet and from Hermann do not accord. The syn. "Virga aurea Canadensis, asterisci folio," Herm. Parad. t. 244, apparently from the figure and certainly from the "*Canadensis*," is the broad-leaved relative of *S. cæsia*, for which I have always kept the name of *S. latifolia*, L. Hermann indicates that it is V. Canadensis Scrophulariæ folio, of the Paris Garden in his time. Plukenet's figure and specimen, t. 235, f. 3, are pretty clearly the same.

S. LATIFOLIA. The specimen which appears to be the original of the species is our *latifolia*, and the habitat is a confirmation. The name written by Linnæus on the sheet is "*lateriflora*," which Smith has corrected to "*latifolia*, vide Sp. Pl." But it is not the ordinary thin-leaved and flexuous-stemmed form of our shady woods and dells; it is rather a state which this species takes on when cultivated in open ground. The syn. of Plukenet, t. 235, f. 4, should be this, by the phrase "latissimo folio, Canadensis glabra;" but the preserved specimens, which quite accord with the figure, must belong to the *S. latissimifolia* of Miller, a broad-leaved axillary-flowered state of *S. elliptica*, Ait., which appears to have been early cultivated in European botanic gardens.

The conclusion formerly reached is to be adhered to, namely, that of the three antecedent names, *S. cæsia*, *flexicaulis*, and *latifolia*, the first and the last are to be maintained, and the *S. flexicaulis* dropped; the plant of the herbarium under this name being only *S. cæsia*, the character and synonymy belonging to *S. latifolia*, while the sole synonym (of Plukenet) under *latifolia* goes to *S. elliptica* of Aiton.

S. VIRGAUREA. The Linnæan specimens are wholly of the European plant.

S. RIGIDA. An unmistakable species; the name suggested by Herm. Parad. Bat., whose figure is cited.

S. NOVEBORACENSIS. Single specimen, its source not recorded. It has long been a puzzle, but it is certainly no *Solidago*, almost certainly not from America, and pretty clearly the *Aster Tartaricus*, Linn. f.

II. *Of Aiton, Hortus Kewensis*, 1789, *preserved in the Banksian Herbarium.*

This is the next authority on the genus, except the edition of Miller's Dictionary cited in the work, in which specific names are given in a tentative way, within brackets. As is well known, the whole editorship was by Solander; but his name not appearing, the work is necessarily cited as that of the elder Aiton, whose name only is on the titlepage. Accordingly, to the latter the species of *Solidago*, *Aster*, &c., published in the Hortus Kewensis have always been attributed.

S. CANADENSIS, L. Various forms of the Linnæan species.

S. PROCERA. Two specimens on one sheet, "Hort. Kew. 1778," the date which is borne by very many of the specimens in the herbarium. They are of *S. Canadensis*, var. *procera*, Torr. and Gray, Fl., which has larger heads than the type, very commonly in ascending dense racemiform clusters, as expressed in Solander's phrase "racemis spiciformibus erectis, inuptis nutantibus;" but he notes in his manuscript, "an racemi semper erecti?" The pubescence of the stem and leaves is hardly "villous," but rather puberulous.

S. SEROTINA. Not really the plant of Torr. and Gray, Fl., but their *S. gigantea*, that is, the completely glabrous form, the *S. glabra*, Desf. &c.

S. GIGANTEA. The *S. serotina* of Torr. and Gray, Fl., &c., namely, the form with some sparse hairiness on the midrib and often the lateral ribs or veins underneath; also "pedunculis hirtis" rather more manifestly than in the preceding. The two are to be taken as of one species, for which the name *serotina* is preferable. The glabrous form is seldom gigantesque; the present one often is so, and may be distinguished as var. *gigantea*.

S. REFLEXA. The specimen, as of the preceding species, is of Hort. Kew. 1778, but all three are in the work said to have been cultivated in 1758 by Philip Miller. This is a badly grown form of *S. Canadensis*. Indeed Solander in his manuscript notes, "Planta primo intuitu videtur monstrosa varietas *S. Canadensis*."

S. LATERIFLORA. Two sheets from "Hort. Kew. 1778," not the Linnæan plant, nor of certain determination, probably a form of *S. ulmifolia*, Muhl. Solander, in his manuscript, notes a resemblance to *S. cæsia*, to which, however, the Linnæan plant (which is *Aster diffusus*) has more likeness.

S. ASPERA. Name taken from Dill. Elth. 411, t. 305, on which the species is founded; specimen from Hort. Kew., 1778, a form of the next species with rather broad and short rugose-veiny leaves, the upper face quite scabrous.

S. ALTISSIMA. Not the Linnæan plant (*vide supra*, p. 177), but that which from this date has passed for it, and for which we must now fall back to the oldest and in the main most appropriate name, *S. rugosa*, Mill. Dict. All the indicated varieties of this polymorphous but well-marked species belong to it, including that which Pursh published as *S. villosa*.

S. NEMORALIS. The species which has always gone by this name. An indigenous specimen from "Virginia Dr. Mitchell," and a cultivated one of Hort. Kew. 1778.

S. ARGUTA. Two sheets; one of Hort. Fothergill, 1778; the other of unknown source, probably an indigenous specimen. Both are the *S. arguta* of Muhlenberg and of most authors anterior to Torr. and Gray's Flora, in which this species was taken up as *S. Muhlenbergii*, Torr. and Gray. I was misled by a wrong identification made by Dr. Boott, to which in 1839 I mistakenly acceded. A third specimen, ticketed by Solander "*S. argutæ* affinis, Hort.," is manifestly of the same species. This restoration brings back the specific name to a plant for which it is appropriate, as it was not for the following species.

S. JUNCEA. The true original of this species, as the Solander manuscript shows, is a small and perfectly characteristic specimen, ticketed "Hudson's Bay, Hutchinson." The specific name was manifestly suggested by the slender and naked racemiform flower-clusters of small heads. It is the *S. arguta*, var. *juncea*, of Torr. and Gray's Flora, the larger and broad-leaved form of which was wrongly taken up as *S. arguta*. The other sheet, of cultivated specimens, one, if not both, from Kew Gardens, may be of the same species, or may be *S. neglecta*, Torr. and Gray, with unusually spreading inflorescence.

S. ELLIPTICA. Two sheets; each with a single specimen. One is of Hort. Kew. 1778, is the upper part of a large plant, with "racemis paniculatis secundis," and is more like the Solidago referred to this species in Torr. and Gray's Flora, now viewed as a large form of *S. Elliottii*, found near the sea-coast of southern New England and New York, the leaves only inconspicuously serrate. The other, brought from "Hort. Reg. Parisiensis" by Houston, is the plant there cultivated of old under the name of *S. latifolia* or *lateriflora*, the *S. latissimifolia* of Miller, as Solander indicates, and probably Plukenet's t. 235, f. 4. It appears to be the species still under cultivation in Europe, with flower-clusters abbreviated and mainly in the axils of comparatively ample leaves, so as to resemble long-cultivated *S. latifolia*, L. It will take the name of *S. elliptica*, var. *axilliflora*. No indigenous specimens known.

S. SEMPERVIRENS, L. Three specimens on two sheets, an indigenous one from Dr. Mitchell, and cultivated ones from Miller and from Kew; all narrow-leaved forms of the Linnæan species.

S. ODORA. Three sheets: one with an indigenous specimen, "Cherokee Country, W. V. Turner, 1769," with an aboriginal name recorded, and is the true plant; so is the original of Plukenet's t. 116, f. 6, preserved among the Plukenet plants at the British Museum. The other specimens are from Kew and from Miller, the latter not clearly of this species; and two large leaves affixed to the sheet belong to something quite different, probably to *Erechthites hieracifolius*.

S. LANCEOLATA, L. One of the sheets contains a specimen of *S. tenuifolia*, indicated as a variety.

S. LÆVIGATA. Same as *S. sempervirens*, L., a form with lanceolate and acute leaves.

S. MEXICANA, L. The Linnæan plant, from Kew Gardens and from Paris. Clayton's plant is a form with narrower and acute upper leaves, nearly the *S. lævigata*, Ait.

S. VIMINEA. Hort. Kew. 1778, a form of the *S. sempervirens*, L. (the name to be adopted for this maritime species), with some pubescence on the upper part of the stem.

S. STRICTA. The cultivated plants, from Miller and from Kew, 1778, on which the species was characterized and published, prove to be identical with the well-marked and much later *S. virgata*, Michx., a pine-barren species of the Atlantic coast. The way in which the name was appropriated to more northern species is as follows. Solander first characterized in his manuscript and ticketed in the herbarium a "*S. parviflora*," on a specimen from Hudson's Bay, collected by Banks (the *S. Terræ-Novæ*, Torr. and Gray), afterwards changed that name for *S. stricta*, at the same time erasing his phrase "paniculato-corymbosa racemis recurvis" and adding to the habitat "prope Novum Eboracum," but not erasing "ad Sinum Hudsonis." The early-cultivated specimens in the herbarium are not good ones, the inflorescence becoming compound, as it often does in the indigenous state; yet the species ought not to have been so mistaken. The name has been used for more than one northern species, but as published in the Hortus Kewensis and cultivated at the time, it belongs altogether to the well-known *S. virgata* of Michaux, which name it supersedes.

There is a specimen from Kew Gardens, 1778, noted by Solander in manuscript as *S. stricta*, var., which is a form of *S. speciosa*, Nutt., and apparently is the original of *S. erecta*, Pursh: *vide infra*, p. 187.

S. LINOIDES of Solander, in herb. (Hort. Lee, 1779), proves to be identical with the original *S. stricta*, that is, *S. virgata*, Michx.; and with this his unpublished character agrees, especially the "caule stricto simplicissimo," and the "racemus terminalis spiciformis," as it does not with the species which Dr. Boott thought he had identified with it.

S. PETIOLARIS. The authentic plant, of Hort. Kew. 1778, was rightly identified by Dr. Boott long ago, and taken up in Torr. and Gray's Flora, and the specimen is not very undeserving of the name. Solander in his manuscript distinguishes two forms, viz., "*α*, foliis integerrimis, calycibus squarrosis," thus noting a distinctive feature, and "*β*, foliis serratis;" the latter, marked "Hort.," is of a very different species, not well made out, but apparently of *S. Virgaurea* of Europe.

S. BICOLOR, L. The Linnæan species.

S. RIGIDA, L. The well-marked Linnæan species.

S. CÆSIA, L. A cultivated and branching form, from "Hort. Chelsea," with unusually racemose-paniculate inflorescence, the *S. gracilis* of Schrader. There is a depauperate indigenous specimen, from "New York, Anderson, 1778," which naturally was thought different, and is ticketed "*S. tenera.*" There is also one of the more normal form of the species, upon which is founded *S. axillaris*, Pursh.

S. AMBIGUA. No native country assigned; but, from the specimen, it may be probably referred to the European *S. Virgaurea*. Under this name, also, an altered form of *S. latifolia*, L., was in early cultivation.

S. MULTIRADIATA. The original in Solander's manuscript is from Labrador, 1765, and is designated as "*Solidaginis minutæ* maxime affinis, cujus forte sole varietas radiis plurimis." Upon the same sheet are similar but more dwarfed specimens, of later date, from "Northwest Coast, Sledge Island, Dav. Nelson;" and from the same station and collector there is a sheet filled with a larger form, which Solander was disposed to refer to *S. Cambrica*; on a third sheet are specimens from Kew Gardens, 1780, also from "Gordon ad Mile End, 1777, Decembri," ticketed "var. *ramosa*," abnormal plants, flowering out of season.

For the species taken up by Pursh from Herb. Banks., see further on, viz. p. 187.

III. *Of Michaux, Flora Boreali-Americana*, 1803.

It is known through tradition that this work was prepared by L. C. Richard, from the collections of the elder Michaux; but he wholly withheld his name, which therefore cannot be cited.

Of the twelve species of *Solidago*, all well determined, four here originate; viz. —

S. PAUCIFLOSCULOSA. A peculiar species of the Florida coast, the only shrubby one.

S. GLOMERATA. A robust large-flowered species of the Alleghany Mountains.

S. VIRGATA. Proves to be the original *S. stricta*, Ait.; vide p. 182.

S. RETRORSA. Is *S. odora*, Ait., while the *S. odora* of Michaux is *S. tortifolia*, Ell.

IV. *Of Willdenow, Species Plantarum*, 1803.

Volume III. part 3, containing the Compositæ, is later than Michaux's Flora, which in some places it refers to.

The species in Willdenow's herbarium are numbered consecutively, and under the several species the sheets are numbered. This was probably done after Willdenow's death. The folios bearing the higher numbers are usually the older and the more authentic for the species. Many of the earlier numbers are badly misnamed, and may be later additions. The Muhlenbergian species here originate, and are represented in the herbarium by named and determinable specimens, which is not the case in Muhlenberg's own herbarium at Philadelphia. The latter proves to be of no account for this genus and *Aster*.

S. CANADENSIS, L. Mostly true; but fol. 1 is *S. cæsia*, and fol. 5 is *S. odora*.

S. PROCERA, Ait. The plant of the Hortus Kewensis.

S. SEROTINA, Ait. The plant of Torr. and Gray's Flora, having some pilosity on the ribs of the leaf beneath, the *S. gigantea*, Ait.

S. GIGANTEA, Ait. Fol. 3 is the authentic specimen, from Muhlenberg, glabrous, the true *S. serotina* of Aiton; fol. 1, 2, are undeveloped cultivated specimens of other species.

S. CILIARIS, Muhl. in litt. Is *S. juncea*, Ait.

S. REFLEXA. Fol. 2 is the authentic plant, and apparently of Aiton, viz. a form of *S. Canadensis*; fol. 1 may be a form of *S. rugosa*, Mill.

S. LATERIFLORA. Not the Linnæan plant, but the plant early cultivated under this name, viz. *S. elliptica*, var. *axilliflora*.

S. ASPERA, Ait. The plant of Aiton, viz. a form of *S. rugosa*, Mill.

S. ALTISSIMA, L. Fol. 1 is a form of *S. Canadensis:* fol. 2, which accords with Willdenow's character, is *S. rugosa*, Mill., with narrow leaves.

S. RUGOSA, Mill. From Muhlenberg; with broadly oblong and not rugose but unusually scabrous leaves.

S. SCABRA, Muhl. in litt. Same as the preceding, with smaller and more serrate leaves, rugose-veiny and scabrous beneath, glabrous and nearly smooth above. But Muhlenberg in his manuscript Florula Lancastriensis evidently describes not this, but *S. procera*, Ait.

S. NEMORALIS, Ait. Only a radical leaf represents the species; the flowering specimen and two large radical leaves are of *S. patula*, Muhl. Ticketed "Fintlemann," therefore cultivated. Willdenow's own description is incongruously made up of the two.

S. PATULA, Muhl. in litt. Three sheets, apparently all from Muhlenberg. One is named "*S. angulata*, Muhl.," in the handwriting of Sprengel. Willdenow singularly omits all mention of the characteristic scabrosity of the upper surface of the leaves, which under the preceding species he has described from similar and misplaced leaves.

S. ULMIFOLIA, Muhl. in litt. Dwarf and scanty specimen of the Muhlenbergian species.

S. ARGUTA, Ait. No specimen.

S. JUNCEA, Ait. No specimen which belongs here, but one so named is *S. nemoralis*, from Muhlenberg.

S. ELLIPTICA, Ait. No specimen.

S. SEMPERVIRENS. Cultivated specimens of the species, with narrow and acute leaves.

S. ODORA, Ait. Three folios of this species, and one of *S. nemoralis*, from Kinn.

S. BICOLOR, L. The well-known species.

S. PETIOLARIS, Ait. The plant of fol. 2 "v. v." is European *S. Virgaurea*. Fol. 1 contains an indigenous *S. speciosa*, Nutt., from Muhlenberg.

S. STRICTA, Ait. Truly the species of Solander, viz. *S. virgata*, Michx., a leafy cultivated specimen, from Hunnemann, probably sent from some English garden.

S. LANCEOLATA, L. A cultivated and an indigenous specimen, the latter from Richard.

S. CÆSIA, L. Fol. 2 and 3 are true, from Muhlenberg; fol. 1 is some other cultivated plant.

S. HISPIDA, Muhl. in litt. Upper part of a plant of *S. bicolor*, var. *concolor*.

S. LÆVIGATA, Ait. Two folios of the broader-leaved *S. sempervirens*, sent by Muhlenberg. "Pedunculi villosi" does not apply to them; they are barely pubescent.

S. MEXICANA, L. From Hunnemann; same as the foregoing.

S. VIMINEA, Ait. Cultivated specimen of a narrow-leaved, less succulent, open-paniculate state of *S. sempervirens*, L.

S. FLEXICAULIS, L. Three folios of *S. latifolia*, Torr. and Gray.

S. AMBIGUA, Ait. Cultivated forms, apparently of European *S. Virgaurea*, and a specimen perhaps of *S. latifolia*, L., in an altered condition.

S. MULTIRADIATA, Ait. Some of the specimens apparently true; one is *S. rugosa*, Mill.

S. RIGIDA, L. From Muhlenberg.

S. no. 15986, sent by Muhlenberg as No. 300, is *S. Canadensis*, var. *scabra*, Torr. and Gray's Flora, and apparently the *S. scabra* of Muhlenberg, according to the description in his unpublished Flora Lancastriensis. Muhlenberg's own herbarium in its existing state throws no light upon the question.

V. *Of Willdenow, Enumeratio Plantarum Hort. Reg. Berolinensis*, 1809.

S. RECURVATA. Cultivated plant, best described as between *S. gracilis*, Poir. (a derivative of *S. cæsia*) and *S. ulmifolia*, not matched by any indigenous specimens. A plant cultivated under this name in the Berlin Garden, 1838, 1839, seems like a hybrid between *S. cæsia*, var. *paniculata*, and *S. Canadensis*.

S. LIVIDA. Cultivated plant, best described as between *S. fuscata*, Desf., and *S. cæsia*, var. *paniculata*. Some indigenous specimens of *S. cæsia* seem to indicate this as its original.

S. HIRTA. Folios 2 and 3 belong to *S. rugosa*, Miller, a form with erect inflorescence and rather large heads; and fol. 1, an imperfect and uncertain specimen, may be of the same species.

S. LITHOSPERMIFOLIA. Two sheets; same as *S. viminea*, Ait., but more puberulent and broader-leaved; being probably a state of *S. sempervirens* much changed under long cultivation. But the aspect of the cultivated plant is very unlike that of *S. sempervirens*.

S. FRAGRANS. Cultivated plant: a narrower-leaved form of *S. lateriflora*, Willd., Spec., viz. *S. elliptica*, var. *axilliflora*.

VI. *Of Poiret, Dict.* (*Enc. Meth.*) viii. 1808.

The original species are the following, including those of Desfontaines, Cat. Hort. Par., or rather Tableau, Bot. Mus. 1804.

S. GLABRA, Desf. The *S. serotina*, Ait. Still common in European cultivation.

S. CONFERTA, Poir. Described from herb. Desfontaines; is *S. nemoralis*, Ait., as appears from the original, now in the herbarium of Dr. Cosson.

S. GRACILIS, Poir. A slightly changed form of *S. cæsia*, L., cult. Hort. Paris. &c.

VII. *Of Poiret, Suppl.* v. 461, 1817.

S. CORYMBOSA, Poir.; of unknown origin, was founded on a form of *S. Virga-aurea*, preserved in herb. Poir., now Cosson.

S. MULTIFLORA, Hort. Par. See Desf. Cat. *infra*.

VIII. *Of Pursh, Flora Americæ Septentrionalis*, 1814; *original species only, most of them taken up from Herb. Banks, really from Solander's names.*

S. VILLOSA. The *S. altissima* β, Ait. Kew., a thin-leaved and hairy-stemmed variety of *S. rugosa*, Mill.

S. PYRAMIDATA. From "Herb. Enslen." The *S. pilosa*, Walt., which is also *S. fistulosa*, Mill. Dict.

S. ASPERATA. Is *S. patula*, Muhl. Not now observed in the Banksian herbarium, but was once identified there by Dr. Boott, and it was named by Pursh in that of Lambert.

S. SAROTHRÆ. From Lewis and Clark's collection; *Gutierrezia Euthamiæ*.

S. ERECTA. No specimen in the Banksian herbarium is so named; but Pursh probably had in view the plant referred to as the *S. stricta* β of Solander in that herbarium, which is probably a narrow-leaved form of *S. speciosa*, Nutt. More evidence would be required to supersede the latter name.

S. MACROPHYLLA. There is no specimen so named to be found in the Banksian herbarium (nor is there any of *S. squarrosa* of Pursh's time); but I confidently identify Pursh's species with a large specimen of *S. thyrsoidea*, Meyer, collected in 1779 by Hallgren on Bisque Island in the Bay of St. Lawrence, which is ticketed by Solander, "*S. pratensis*, var. caule villosiusculo." Pursh's is the earliest-published name of this species, and may be adopted.

S. HUMILIS. Founded by Solander on a specimen collected by Banks himself in Newfoundland, and on the shores of Hudson's Bay, taken up by Richardson, Boott, &c.

S. ELATA. The character is only "S. caule piloso tereti, foliis lanceolatis subtus pilosiusculis, racemis erectis, ligulis elongatis. Herb. Banks, MSS." It is not referred to by Solander in his note-books. There are two specimens so named by him, on separate sheets; but it seems that they were thought too uncertain for publication, as indeed they are.

IX. *Of Desfontaines, Cat. Hort. Reg. Paris., ed.* 3, 1829.

S. GLABRA. Same as *S. serotina*, Ait., first published in Poir. Dict.

S. NUTANS. A form of *S. Canadensis*, L.

S. INTEGRIFOLIA. A cultivated state of *S. sempervirens*, L.

S. HUMILIS. A low form of *S. rugosa*, Mill., with inflorescence not normally developed under cultivation.

S. FUSCATA. Species of unknown source, introduced into the Paris Garden about the year 1828, first mentioned in the *additamentum* to Desfontaines' Catalogue, p. 362, as *S. fusca*, Hort. Par.; in the *adnotationes*, p. 402, characterized as *S. fuscata*. It is a smooth and glabrous and rather freely branching plant, in the virgately thyrsoidal and not at all secund inflorescence recalling *S. puberula*, but with broader and obtuse involucral bracts, the stems purplish. Not identified with any indigenous species.

S. PLANTAGINEA. The same as *S. elliptica*, Ait.

S. MULTIFLORA. First published in Poir. Suppl. v. 461, in cultivation down at least to 1869; it appears to be related to *S. ulmifolia* as *S. humilis* is to *S. rugosa*, viz. a form in which the leaves have become firmer and the panicles less evolute by exposure under cultivation. No indigenous specimens well correspond.

S. ASPERULA. Apparently the same as the plant cultivated in the Paris Garden under the unpublished name of *S. rigidula*, Bosc, from about 1828 to 1831, not recognized in the wild state, perhaps derived from the preceding or from *S. Elliottii*, or from *S. rugosa*, which the hirsute pubescence of the upper part of the stem strongly suggests.

S. GRANDIFLORA. This I take to be a tall cultivated state of *S. littoralis*, Savi, of the Italian coast, a species quite distinct from *S. Virgaurea*. "*S. Narbonensis*, Pourret, in Act. Tolos. iii. 329," which, if actually published, has been overlooked, is perhaps the same species.

X. *Of De Candolle, Prodromus*, v. 1836.

S. CLELLÆ. Probably *S. elliptica*, Ait., var. *axilliflora*, Gray, and the same as *S. dubia*, Scop. Del. Insub. t. 10.

S. SCABRIDA. A Mexican species, seemingly only a larger-flowered *S. Canadensis*, var. *scabra*.

S. DECEMFLORA, is *S. nemoralis*, Ait., from Texas.

S. FLABELLIFORMIS, Wendl. (*S. flabellata*, Schrader, cited by

Sprengel as a syn. of his *S. arguta*), appears to be *S. livida*, Willd. Enum.

S. Schraderi. Cultivated plant; looks like a hybrid between *S. cæsia*, var. *paniculata*, and *S. Canadensis* (inflorescence not well developed); while the plant cultivated under the name in the Paris Garden in 1869 is purely the former.

S. carinata, Schrader, in litt., is *S. riminea*, Ait., viz. *S. sempervirens*, var. *riminea*, Gray.

S. lepida. A species of the Northwest coast, collected by Hænke, to which *S. elongata*, Nutt., very closely approaches.

S. confertiflora. Another plant of Hænke's collection on the Northwest coast, very near the variable *S. humilis*, Pursh, probably only a quite glutinous form of it, the *S. glutinosa*, Nutt.

S. spathulata. Came not from "Mexicanis terris," properly so called, but from Monterey in California, and is *S. spiciformis*, Torr. and Gray, Fl., which thus becomes a synonym.

S. rotundifolia. Is a round-leaved form of *S. radula*, Nutt., from Texas.

3. Solidago: *General Disposition of the Admitted North American Species, with the principal Synonyms, at least those not already adduced in Torr. & Gray, Flora N. America.*

§ 1. VIRGAUREA. (*Virga-aurea*, Tourn.)

* Squarrosæ. (§ 1. *Chrysastrum*, Torr. & Gray.)

S. discoidea, Torr. & Gray. A uniformly rayless species.

S. squarrosa, Muhl.

S. petiolaris, Ait., & var. angusta, *S angusta*, Torr. & Gray, Fl.

* * Glomeruliflor æ.

+ Akenes canescently hirsute or pubescent: stem and branches terete, often glaucous.

S. cæsia, L., with var. axillaris (*S. axillaris*, Pursh) and var. paniculata. To the latter is referred *S. gracilis*, Poir., *S. arguta*, Spreng. Syst. (not Ait.), *S. argentea*, Hornem., *S. Schraderi* of the Gardens (that of DC. seems to be an abnormal or hybrid form), and even *S. recurvata*, Willd., all from the Gardens, and altered by cultivation. This species is also the probable parent of *S. livida*, Willd., including *S. flabellata*, Schrader, or *S. flabelliformis*, Wendl.

+ + Akenes canescently hirsute: stem and branches angled, not glaucous.

S. LATIFOLIA, L. excl. syn. Pluk. *S. flexicaulis*, L., ex. syn. & char., not of herb.

S. LANCIFOLIA, Torr. & Gray, in Chapm. Fl. 209.

S. CURTISII, Torr. & Gray; with var. PUBENS, the *S. pubens*, Curtis, in Torr. & Gray.

+ + + Akenes glabrous: inflorescence virgately thyrsoid.

S. MONTICOLA, Torr. & Gray, in Chapm. Fl. *S. Curtisii*, var. ? *monticola*, Torr. &. Gray, Fl.

S. BICOLOR, L. *S. viminea*, Bosc in herb. Poir.; therefore *S. erecta*, DC. Prodr. — Var. CONCOLOR, Torr. & Gray. *S. hispida*, Muhl. in Willd. *S. hirsuta*, Nutt. — Var. LANATA. *S. lanata*, Hook. Fl.

* * * THYRSIFLORÆ.

+ Southwestern species, fully two feet high, with very numerous short and firm entire leaves, uniform up to the inflorescence: pubescence minute, somewhat scabrous and cinereous: heads four lines long.

S. BIGELOVII, Gray, Proc. Am. Acad. xvi. 80. Cinereous-puberulent; leaves oval and oblong, mostly obtuse at both ends, and hispidulous on the margins; thyrsus simple or compound, rather dense, or at length open; involucre broadly campanulate, puberulent; akenes minutely pubescent or glabrate. *S. petiolaris*, Gray in Bot. Mex. Bound. 79, not Ait. Mountains of New Mexico and Arizona; also adjacent Mexico. — It passes into var. WRIGHTII. A form with sometimes narrower leaves, and a simple thyrsus of few heads, inclining to corymbose. *S. petiolaris*, var., Gray, Pl. Wright, i. 94. *S. Wrightii*, Gray, l. c. Southwestern Texas to Arizona.

S. LINDHEIMERIANA, Scheele in Linnæa, xxi. 599. *S. speciosa*, var. *rigidiuscula*, Gray, Pl. Lindh. ii. 222, not Torr. & Gray.

+ + S. Alleghanian species, with thinner and bright green mostly ample and serrate leaves.

++ Of the middle country.

S. BUCKLEYI, Torr. & Gray. A somewhat stately species, obtained from Middle Alabama by Buckley, perhaps even earlier from Lincoln Co., North Carolina, by M. A. Curtis, and later in Jasper Co., Georgia, by Professor Porter.

++ ++ Of the high mountains.

S. GLOMERATA, Michx. Does not well accord with the name, the large heads when well developed being loosely disposed or scattered.

S. SPITHAMÆA, M. A. Curtis.

+ + + Boreal-montane, of difficult and uncertain limitation.

++ Bracts of the involucre acute.

S. MACROPHYLLA, Pursh. *S. thyrsoidea*, E. Meyer, Torr. & Gray, Fl., &c. *S. leiocarpa*, DC. N. New England and Lake Superior to Hudson's Bay.

S. MULTIRADIATA, Ait. *S. Virgaurea*, var. *multiradiata*, Torr. & Gray, Fl. Labrador to Northern Rocky Mountains and Unalaska. — Var. SCOPULORUM. *S. corymbosa*, Nutt. in Trans. Am. Phil. Soc. Higher Rocky Mountains to New Mexico, Utah, &c. — Var. NEO-MEXICANA. A tall form, perhaps quite distinct, two feet high, with numerous heads loosely disposed in approximate axillary as well as terminal clusters, forming a narrow elongated thyrsus. High summit of one of the Mogollon Mountains, *H. H. Rusby*, 1881. And a form approaching it was collected by Dr. Palmer in Utah.

S. VIRGAUREA, L., var. ALPINA, Bigelow. Alpine region of the mountains of Maine, New Hampshire, and Northern New York. Also Hudson's Bay (?).

++ ++ Bracts of the involucre obtuse.

S. HUMILIS, Pursh, not Desf. — Var. GILLMANI is an extreme form of this variable species, with dentate even laciniate leaves and an open compound panicle: growing on sand hillocks on the shores of Lakes Superior and Michigan.

S. CONFERTIFLORA, DC., *S. glutinosa*, Nutt., of Oregon to British Columbia, near the coast, is probably only another form of *S. humilis*.

+ + + + California coast species, with few heads and inconspicuous rays.

S. SPATHULATA, DC. *S. spiciformis*, Torr. & Gray, Fl. Hænke's plant is from Monterey, California.

* * * * PANICULATÆ.

+ *Maritimæ, lævigatæ.*

S. CONFINIS. Apparently pale green; leaves lanceolate and rather short, or the radical obovate; heads small (two lines long), crowded in a dense oblong panicle, not secund; rays small, not surpassing the disk-flowers; akenes canescently pubescent. *S. sempervirens* Gray, Bot. Calif. i. 319, in part. Southern borders of California, collected by Palmer, Cleveland, and Parish.

S. SEMPERVIRENS, L. Besides the synonyms, *S. Mexicana*, L., *S. lævigata*, Ait., and *S. limonifolia*, Pers., the *S. Azorica*, Hochst. in Seubert, Fl. Azorica, is to be added. The indigenous plant is apt to acquire some hirsute pubescence on the inflorescence and the upper part of the stem, and even on some of the leaves, when it grows beyond the influence of salt or brackish water. — Var. VIMINEA, the *S. viminea*, Ait., *S. integerrima*, Mill. Dict., *S. integrifolia*, Desf., and *S. carinata*, Schrader; these are duller-leaved cultivated forms, with some fine appressed pubescence on the inflorescence, evidently the result of prolonged cultivation in European gardens. And *S. lithospermifolia*, Willd., must be a still more altered state, with larger leaves, these somewhat puberulent. No indigenous specimens like it have been found.

S. STRICTA, Ait., also of Pursh, not of later authors. *S. virgata*, Michx. *S. linoides*, Solander, ined. *S. genistoides*, Bertol. This was an unexpected discovery, which leaves no choice other than the restoration of the original name to the species which was well named *S. virgata* by Michaux. — Inseparable from it is var. ANGUSTIFOLIA, *S. angustifolia*, Ell., which in brackish soil appears to pass into the most slender and narrow-leaved form of *S. sempervirens*.

S. FLAVOVIRENS, Chapm. Fl. 211. Even this shows indications of passing into a broad-leaved form of *S. stricta*, Ait.

+ + *Unicostatæ, agrestes.*

++ Slender, wholly glabrous and smooth, always rayless.

S. GRACILLIMA, Torr. & Gray.

++ ++ Minutely puberulent, obscurely venulose: thyrsoid panicle of small heads not at all secund.

S. PUBERULA, Nutt. — Var. PULVERULENTA, Chapm., viz. *S. pulverulenta*, Nutt., and *S. ovorata*, Bertoloni.

++ ++ ++ Leaves obscurely veined, with only midrib prominent, mainly entire; cauline closely sessile: heads small, in a broad panicle of racemiform recurving clusters: rays 3 to 5, rarely none.

= Leaves all entire and glabrous, more or less pellucid-punctate.

S. ODORA, Ait., with var. INODORA.

S. CHAPMANI, Gray, Proc. Am. Acad. xvi. 80. *S. odora*, in part, Chapm. Fl. *S. tortifolia* of Curtiss, distrib. no. 1351. Florida. Between *S. odora* and *S. pilosa.*

= = Leaves more or less serrulate, scabrous or pubescent, very numerous up to the inflorescence.

S. TORTIFOLIA, Ell. *S. retrorsa*, Pursh, and Nutt, not Michx.

S. PILOSA, Walt. *S. fistulosa*, Mill. Dict. and the synonymy in Torr. & Gray, Fl.

++ ++ ++ ++ Leaves comparatively ample and obviously but not prominently veiny, of rather firm texture, perfectly glabrous and smooth, never much serrate: heads middle sized, crowded in usually narrow and erect thyrsoid inflorescence, not secund.

= Atlantic species: akenes glabrous or nearly so: rays conspicuous, five or six.

S. ULIGINOSA, Nutt. Jour. Acad. Philad. vii. 101. *S. stricta*, Hook. Fl. ii. 4, in part; Torr. & Gray, Fl. ii. 204, not Ait. Although Nuttall appears to have had more than one plant in view, this is really the one upon which his species was founded.

S. SPECIOSA, Nutt., with var. ANGUSTATA, and var. RIGIDIUSCULA, Torr. & Gray.

= = Pacific and Rocky Mountain species: akenes pubescent: rays more numerous and smaller.

S. GUIRARDONIS, Gray, Proc. Am. Acad. vi. 543.

S. SPECTABILIS. *S. Guirardonis*, var. *spectabilis*, Eaton, Bot. King. 154.

++ ++ ++ ++ ++ Leaves veiny, and at least the lower serrate; heads racemosely paniculate and when well developed secund, commonly in recurving racemiform clusters: Atlantic species.

= Leaves shagreen-scabrous on the upper face, ample; stem strongly angled.

S. PATULA, Muhl. *S. asperata*, Pursh, as to herb. Lamb. *S. angulata*, Spreng. in herb. Willd.; Schrader in DC. Prodr. Var. STRICTULA, a southern small-leaved and stricter form. *S. salicina*, Ell., ex char. *S. scabra*, Hook. Comp. Bot. Mag.

= = Leaves on both faces and stem minutely cinereous-pubescent: flowering in spring; the inflorescence hardly secund.

S. VERNA. M. A. Curtis in Torr. & Gray, Fl.

= = = Leaves thin and loosely veiny, or firmer when growing in arid places; but veins and veinlets on the lower face generally conspicuous and reticulated; heads small; bracts of the involucre rather few and narrow; akenes pubescent.

[S. ELLIPTICA, Ait. Unknown in the wild state; see p. 181. *S. plantaginea*, Desf., is the same.]

a. Rays few (1 to 3) or none: leaves clasping.

S. AMPLEXICAULIS, Torr. & Gray, but not of Martens.

b. Rays 4 to 6, or rarely none: leaves sessile by a narrow base, pinnately veiny: pubescence of spreading hairs, or none.

S. RUGOSA, Mill. Dict. ed. 6; Willd. Spec. iii. 2058. *Virga-aurea*, &c., Dill. Elth. 406, 410, 411, t. 304, 305, 308, mentioned by Linnæus under his *S. altissima*, but not referred to it, as was commonly supposed, and not really any part of the Linnæan *S. altissima*, for which it was taken by subsequent botanists. *S. altissima* and *S. aspera*, Ait. Kew.; Willd., &c. *S. scabra*, Muhl., in Willd., l. c. *S. villosa*, Pursh. *S. humilis*, Desf., a low form, with inflorescence hardly spreading or secund. *S. hirta*, Willd. Enum. *S. rigidula*, Bosc, in hort. Par. (?) *S. asperata*, Soland. in herb. Banks., therefore of Pursh as to the type. *S. pilosa*, *recurvata*, *Virginiana*, and *altissima*, as well as *rugosa*, Mill. Many but indefinite varieties.

S. ULMIFOLIA, Muhl. in Willd. *S. lateriflora*, Ait. Kew., but not of Linnæus. *S. multiflora*, Desf., appears to be a cultivated form of it. — Var. MICROPHYLLA, *S. microphylla*, Engelm. in herb., is a rigid and small-leaved southern form, from Texas.

= = = = Leaves of firmer texture and less conspicuous reticulation, not scabrous or hardly so, commonly glabrous as are the stems: bracts of the involucre broader, obtuse.

S. ELLIOTTII, Torr. & Gray, connects with the preceding. It is *S. elliptica* (?), Ell., also of Torr. & Gray, Fl., as to plant from New York, &c. But not the original *S. elliptica*, of which no indigenous representative has yet been identified.

S. LINOIDES, Torr. & Gray, Fl., but not of Solander.

S. NEGLECTA, Torr. & Gray, Fl. Not identified with any older species.

S. TERRÆ-NOVÆ, Torr. & Gray, Fl. Still insufficiently known.

S. BOOTTII, Hook., Torr. & Gray, Fl. *S. juncea*, DC., not Ait. — Var. LUDOVICIANA, is a dubious form, with larger heads and leaves. Var. BRACHYPHYLLA, the *S. brachyphylla*, Chapm. in Torr. & Gray, Fl., is a remarkably small-leaved and usually rayless form of Georgia and Florida, passing into the typical *S. Boottii.*

S. ARGUTA, Ait., Muhl., Pursh, DC., &c.; the *S. Muhlenbergii*, Torr. & Gray. See p. 180. *S. verrucosa*, Schrader, is probably the same, but is known only by the figure.

S. JUNCEA, Ait., &c. *S. ciliaris*, Muhl. in Willd. *S. arguta*, Torr. & Gray, Fl., not Ait. Name refers only to the inflorescence, which reminded Solander of that of some species of *Juncus.*

+ + + Not maritime: leaves more or less triple-ribbed (of which there are indications in the lower leaves of one or two of the preceding species, and some of the following show it obscurely). — *Triplinerviæ.*

++ At least the stem and mostly the bright green leaves smooth and glabrous or nearly so, not cinereous or canescent: inflorescence (when well developed) secund in commonly spreading racemiform clusters which are collected in a terminal compound panicle: akenes more or less pubescent.

= Leaves of firm texture, rather rigid, acute or acuminate, the slender lateral ribs hardly seen in the upper cauline: bracts of the involucre firm and broadish, all obtuse.

S. MISSOURIENSIS, Nutt., with syn. as in Torr. & Gray, Fl. — Var. MONTANA. The low or dwarf mountain form, with panicle usually compact, the heads sometimes hardly secund, the leaves mostly all entire. This is the original *S. Missouriensis*, Nutt. Jour. Acad. vii. 32, from the "Upper branches of the Missouri," collected by Wyeth, and it extends from Saskatchewan nearly to the Pacific. — Var. EXTRARIA, is a robust and broad-leaved form, with larger heads and more conspicuous rays; of the Rocky Mountains in Colorado and New Mexico.

S. SHORTII, Torr. & Gray. Formerly known only on the banks of the Ohio, it has recently been detected in Northern Arkansas, by Professor F. L. Harvey.

S. MARSHALLI, Rothrock, in Wheeler, Rep. vi. 146. S. Arizona.

= = Leaves thinner, sometimes membranaceous: bracts of the involucre chiefly linear, obtuse.

S. Leavenworthii, Torr. & Gray. Southern Atlantic States near the coast.

S. rupestris, Raf. Probably an extreme glabrous and slender form of *S. Canadensis*, growing in shade.

S. serotina, Ait., which, as already stated, is the *S. gigantea* of Willdenow and American botanists, the *S. glabra*, Desf.; and a form of it *S. Pitcheri* of Nuttall. — Its var. gigantea, that is, *S. gigantea*, Ait., but the *serotina* of Willdenow and of later authors, differs only and very variably in having some pilose or hirsutulous pubescence on the veins or the under surface of the leaves.

++ ++ Minutely pubescent or glabrate, not cinereous or scabrous: leaves thinnish, veiny, and with lateral ribs sometimes evident but often obsolete: panicle usually erect and thyrsiform, with the heads hardly at all secund: involucral bracts small, thin and narrow. Intercalated between the preceding aud the following, to both which the species are nearly related, yet as much so to *S. rugosa*. Northwestern species.

S. lepida, DC. Not too well distinguished from the next, by its fewer and larger usually glomerate heads, little surpassing the upper leaves, and the subulate-linear acute involucral bracts. Belongs to the Northwest Coast, Alaska, &c.

S. elongata, Nutt. *S. stricta*, Less. in Linnæa. *S. elata*, Hook. Fl. Eastward it seems to pass into *S. Canadensis*.

++ ++ ++ At least the stem pubescent or hispidulous-scabrous, either hirsutely or canescently: branches of the panicle when well developed secund.

= Leaves tapering gradually to an acute or acuminate apex: panicle open: bracts of the involucre narrow and thin: rays small and short.

S. Canadensis, L. Also the original *S. altissima*, L., founded on Martyn's Hist. Pl. 14, t. 14, but not of most subsequent authors, who have followed the conjectural references to Dill. Elth. (See *S. rugosa*.) *S. reflexa*, Ait., Willd., &c. *S. nutans*, Desf. *S. longifolia*, Schrader in DC. — Var. procera, Torr. & Gray, the *S. procera*, Ait., &c., and *S. eminens*, Bischoff. — Var. scabra, Torr. & Gray. Chiefly a southern form, apparently extending well into

Mexico, under the name of *S. scabrida*, DC. — Var. CANESCENS, of S. W. Texas and S. New Mexico, is an outlying form, perhaps a distinct species, which from its hoariness and the broader bracts of the involucre, might be confounded with narrower-leaved and soft pubescent forms of *S. nemoralis*. — Var. ARIZONICA, the *S. mollis*, Rothrock in Wheeler, Rep. vi. 146, and in the heads approaching the Mexican *S. velutina*, DC., is another ambiguous plant, with low stems and comparatively large heads, the thin involucral bracts acutish; of New Mexico and Arizona.

= = Leaves obtuse, or abruptly apiculate or acutish, of firm or coriaceous texture, the upper entire; pubescence all close, cinereous or canescent, or scabro-hispidulous; the lateral ribs commonly incomplete and not rarely obscure or even wanting: panicle mostly compact: bracts of the involucre broadish, obtuse, and of firm texture: rays rather few but large, golden yellow.

a. From cinereous to canescent with fine and soft or at length minutely scabrous pubescence: leaves firm, but not rigid.

S. CALIFORNICA, Nutt. *S. velutina*, var. panicula contracta, DC. The plant of Hænke is from Monterey, California, not Mexico. — Var. NEVADENSIS is hardly to be distinguished from the next species.

S. NEMORALIS, Ait. *S. hispida*, Muhl. in Willd. *S. conferta*, Poir. Dict. viii. 549. *S. cinerascens*, Schweinitz in Ell. *S. decemflora*, DC. *S. puberula*, DC., not Nutt. — Var. INCANA. *S. mollis*, Bartl. in DC., &c. *S. incana*, Torr. & Gray.

S. NANA, Nutt., of the Rocky Mountains, &c.; has few and larger almost corymbosely disposed heads, and broader involucral bracts; otherwise the larger forms are too like *S. nemoralis*.

b. Hispidulous-scabrous, rigid, green.

S. RADULA, Nutt. *S. rotundifolia*, DC. *S. scaberrima*, Torr. & Gray, Fl. *S. decemflora*, Gray, Pl. Lindh., not DC.

c. Scabro-puberulent, somewhat cinereous; the very small leaves with hardly any lateral ribs.

S. SPARSIFLORA, Gray, Proc. Am. Acad. xii. 58. A var. SUBCINEREA, from S. Arizona, *Lemmon*, indicates an unsuspected relationship with *S. nemoralis*. And, from the Mogollon Mountains, New Mexico, Mr. Rusby sends a form between the latter and *S. Canadensis*, var. *canescens*. Further study of fuller materials is required.

= = = Leaves thinnish, puberulent, but green, broad, acute, divergently triplinerved and veiny, serrate: involucral bracts narrowly oblong, obtuse: rays few.

S. Drummondii, Torr. & Gray. Triplinerved, but most related to such venose species as *S. amplexicaulis* and *S. rugosa.*

* * * * * Corymbosæ.

+ Leaves not triplinerved, flat; cauline very numerous: akenes glabrous,

++ Turgid, 10–15-nerved.

S. rigida, L.

S. corymbosa, Ell., not Poir., which is only *S. Virgaurea.*

++ ++ Akenes barely 5-nerved.

S. Ohioensis, Riddell.

+ + Leaves somewhat conduplicate-carinate; lower slightly triplinerved.

S. Riddellii, Frank in Riddell, Synops. *S. amplexicaulis*, Martens.

S. Houghtoni, Torr. & Gray, in Gray, Man., ed. 1, 211.

+ + + Leaves flat, smooth and glabrous, narrow, somewhat triplinerved or 3-nerved, lucid.

S. nitida, Torr. & Gray. Louisiana and Texas.

S. pumila, Torr. & Gray. *Chrysoma pumila*, Nutt.

§ 2. EUTHAMIA.

* Western species, more paniculate.

S. occidentalis, Nutt.

* * Eastern species; fastigiate-cymose and glomerate.

S. lanceolata, L.

S. tenuifolia, Pursh. This proves to be the *Erigeron Carolinianum*, L., that is, *Virga-aurea Carol.*, &c., Dill. Elth. 412, t. 306, fig. 394.

S. leptocephala, Torr. & Gray. Louisiana and Texas.

§ 3. CHRYSOMA.

S. paucifloscuLosa, Michx. *Chrysoma solidaginoides*, Nutt.

*** *Mexican Species.* Remarkably few are known, and these have nearly all been mentioned in the foregoing enumeration.

S. SCABRIDA, DC., is hardly other than an extreme form of *S. Canadensis*, var. *scabra*.

S. VELUTINA, DC., seems to be a distinct species of the same group, and has recently been collected by Dr. Palmer in the north of Mexico. The variety from "Real del Monte. Hænke," is to be excluded, being *S. Californica* from Monterey, California.

S. GONOCLADA, DC., is a peculiar species not to be confounded with *S. odora* (a form of which, named *S. gonoclada* by Schultz, occurs in Mexico), which is also *S. puncticulata*, DC.; but that was from Texas, not Mexico.

S. PANICULATA, DC., is the same as *S. gonoclada*. But the *S. Mexicana*, HBK., doubtfully referred to it, is truly the *S. Mexicana*, L., viz. *S. sempervirens*, L. To it belongs no. 124 of my distribution of plants of Ghiesbreght from Chiapas.

S. SIMPLEX, HBK., is a peculiar species, of the *S. Virgaurea* group, which Dr. Schaffner has apparently rediscovered in his *S. Pseudo-Virgaurea*, ined.

S. SPATHULATA, DC., of the same group, proves to be Californian. See p. 189.

II. *Novitiæ Arizonicæ, etc.: Characters of the New Plants of certain Recent Collections, mainly in Arizona and adjacent Districts, &c.*

The principal *Polypetalæ*, as well as the *Apetalæ*, &c., of the recent collections in our hands will soon be published by Mr. Watson.

BRAYA OREGONENSIS. Humillima, fere glabra; caulibus foliosis subpollicarsibus e caudice multicipiti cæspitosis; foliis confertis spathulato-linearibus integerrimis ciliolatis coriaceis glaucescentibus; racemo intra folia sessili vel in pedunculo scapiformi parum exserto paucifloro; silicula ovata sectione subtereti acuta stylo gracili persistente superata 1–2-sperma (ovulis in loculis binis pendulis), valvis rigido-coriaceis, septo pertenui. — Union Co. Oregon, on sterile subalpine ridges, coll. June, 1880, in fruit, May, 1881, in flower, *W. C. Cusick*. This peculiar little Cruciferous plant I had named *Cusickia*, and the discoverer has partially distributed it under this name. But I perceive that it should be referred to the somewhat polymorphous genus *Braya* (including Brown's *Platypetalum*), and that it may fairly be associated with *B. pilosa* and *B. purpurascens*, both illustrated by Hooker, notwithstanding the reduction of the ovules to a pair in each cell and the maturation of only one or two large seeds.

Æsculus Parryi. *Æ. Californicæ* affinis, frutex humilis; foliis 3–5-foliolatis; foliolis obovatis obtusis subcoriaceis brevissime petiolulatis subtus cano-tomentosis; floribus brevipedicellatis; calyce campanulato ad medium usque æqualiter 5-fido petalisque extus tomentosis; filamentis validioribus minus exsertis. — Northern part of Lower California, April, 1882, *Parry*, *Jones*, and *Pringle*.

Crotalaria Pringlei. Simplicifolia, e basi suffrutescente perenni ramosissima, pilis longis albidis villoso-sericea; foliis oblongo-lanceolatis (semipoll. ad pollicarem) subsessilibus utrinque obtusis mucronatis, aliis exstipulatis, aliis stipulis solitariis vel binis lanceolato subulatis secus caulem breviter decurrentibus instructis; pedunculis 2–3-florisfolium raro superantibus; calycis lobis inæqualibus; legumine ovali glaberrimo. — Santa Catalina Mountains, South Arizona, *Pringle*. This is from an interesting collection made by Mr. C. C. Pringle, in the southern part of Arizona, in the summer of 1881.

Dalea Lemmoni, Parry in coll. *D. brachystachi* affinis (vide Pl. Wright, ii. 40), gracilior; foliolis 3–5-jugis paullo angustioribus; spicis longius pedunculatis ovatis; bracteis (exterioribus fere glabris) calycisque lobis longius aristato-productis, illis insigniter albo-plumosis; corolla ut videtur purpurascentes. — Near Fort Bowie, Apache Pass, South Arizona, Lemmon, 1881. This and numerous following species form a part of the fruits of two laborious and trying explorations in Southern Arizona, made by Mr. J. G. Lemmon and Mrs. Lemmon. This interesting district has been made accessible by the opening of the Southern Pacific Railroad, the directors of which have rendered very essential and highly appreciated service to science by the facilities which they have afforded to the above-mentioned and to other botanists.

Dalea Ordiæ. *D. albifloræ* sat similis, sed glabella, caulibus suffruticosis foliisque tantum puberulis; foliolis sæpius angustioribus; spicis numerosioribus brevius pedunculatis ex ovata cylindraceis tenuiter sericeis; bracteis minoribus; calycis lobis lato-subulatis tubo glandulis insigniter notato fere dimidio brevioribus; corolla læte alba. — Plains near Bowie and Rucker Valley, S. Arizona, *Lemmon*, 1881. Also collected in the previous year by Mrs. Dr. Ord, whose name this handsome and abundantly floriferous species may commemorate.

Dalea Pringlei. *D. lævigatæ* proxima, etiam glaberrima spicis oblongis cylindraceisque villosissimis exceptis; caulibus gracilibus e basi suffrutescente pedalibus; foliolis (lin. 1–2 longis) obovatis seu ovalibus punctatis; bracteis ex ovata acuminatis flore parum brevioribus; calycis lobis deltoideo-subulatis tubo æquilongis corolla parva læte purpurea æquantibus. — Foot-hills of the Santa Catalina Mountains, S. Arizona, *Pringle*, April and May, 1881.

Coursetia microphylla. Foliolis 5–8-jugis absque impari (lin. 1–3-longis) subcoriaceis oblongis cuspidato-mucronatis sericeo-pubescentibus demum glabratis, venis perobscuris; racemis laxe paucifloris; calycis glandulosi lobis e basi lata lanceolatis tubo sublongioribus; corolla alba nunc roseo tincta, carina obtusiuscula; legumine glanduloso toroso compresso 5–8-spermo. — Rocky cañons of the Santa Catalina Mountains, S. Arizona, flowering in April, *Pringle*, *Lemmon*. — Shrub with long and slender flowering branches; the fruit obtained only by Mr. and Mrs. Lemmon.

Cracca Edwardsii, Gray, Pl. Wright, ii. 35. *C. glabrescens*, Hemsley, Biol. Centro-Amer. i. 262, as to Mexican plant, here referred by an oversight. Seems to vary widely. Taking the loosely branching and diffuse specimens with sparse sericeous pubescence as the type, the leaflets of which are commonly 9 or 7, and are sometimes an inch long, there are two marked varieties to be noted, viz.

Var. sericea, with dense sericeous pubescence apparently persistent on the lower face of the smaller oblong leaflets. This Mr. Lemmon collected, in the spring of 1881, in Spring Creek Cañon, of the Santa Catalina Mountains; and Mr. Pringle about the same time in the Santa Rita Mountains. It is distinguished from *C. mollis*, Benth. (as is the species), by the less attenuated calyx-segments being decidedly shorter than the carina, inflorescence less villous, and the ovary glabrous.

Var. glabella, with far less and minuter or sometimes quite deciduous pubescence, lower and strict stem, and more numerous leaflets, these from oval to roundish, on the lower leaves 9 or 11, on the others 15 to 17 in number. This was collected by *Wright*, and again by *Lemmon* in 1881, along with the typical form.

Rubus lasiococcus. Inter *R. pedatum* et *R. Chamæmorum*; caulibus herbaceis humifusis cinereo-puberulis; stipulis ovatis subscariosis; foliis cordato-rotundis 3–5-lobatis cum paucis trisectis, lobis segmentisve obtusissimis crebre duplicato-dentatis; pedunculis ramos breves paucifoliatos terminantibus 1–2-floris; calycis segmentis ovatis acuminatis integerrimis petalis obovatis albis brevioribus; ovariis paucis (5–9) etiam drupellis carnosis tomentulosis. — Oregon, near Mount Hood, *E. Hall*, 1871 (no. 140), *J. Howell*, 1878. — In the account of Hall's collection this was inadvertently called *R. pedatus* (some of which was mixed with it); from which it is quite different, being much less slender, with thicker leaves which are seldom divided, some of the larger not unlike small ones of *R. Chamæmorus.* Flowers not much larger than those of *R. pedatus*, the petals broader, five lines long. The canescent dense tomentum of the ovaries is seen even on the mature drupelets.

RIBES VIBURNIFOLIUM. *Ribesia*, modo *R. nigri* resinoso-atomiferis; foliis ovato-rotundis utrinque obtusissimis (nec cordatis nec plicatis) inciso-paucidentatis nunc obsolete trilobis glabris (petiolo excepto) demum coriaceis (pollicem longis): racemo subsessili corymbiformi plurifloro, pedicellis filiformibus, bracteis scariosis caducis; calycis tubo turbinato demum oblongo, limbo rotato 5-partito roseo, lobis ovalibus; petalis minimis patentissimis viridulis filamentisque brevissimis margini disco lato plano insertis. — Northern part of Lower California, near All Saints Bay, *Parry*, *Pringle*, and *Marcus Jones*, April, 1882. A straggling bush, so peculiar that the acute collectors did not recognize the genus. Yet the flowers have all the characters of the *Ribesia* section, and the conspicuous glands of the leaves, young shoots, pedicels, &c., are just like those of *R. nigrum.*

HOUSTONIA WRIGHTII. Pumila (2–5-pollicaris), e radice ut videtur perenni multicaulis, suberecta, fere glabra; stipulis scariosis subintegris; foliis linearibus muticis, imis sublanceolatis; cymulis foliosis; calycis lobis subulato-lanceolatis tubo brevissimo 2–3-plo longioribus corollæ subinfundibuliformis (lin. 3–4-longæ) tubo sæpius dimidio brevioribus; capsula subdidymo-globosa $\frac{3}{4}$ libera; seminibus in loculis 5–8 crateriformibus. — *Hedyotis humifusa*, Gray, Pl. Wright, i. 82, & *Oldenlandia humifusa*, Pl. Wright, ii. 68, non Pl. Lindh. ii. 216. On the Limpio, Western Texas, *Wright*, Fort Whipple, Arizona, Palmer, 1865, no. 75. New Mexico, *Thurber* (?), *Greene*, 1877. Arizona in the San Francisco Mountains, Greene, 1880, no. 460. Arizona, *Dr. Budd*, *Pringle*, *Lemmon*, 1881, no. 512. Santa Magdalena, New Mexico, 1881, *G. R. Vasey.* The tube of the corolla is sometimes almost twice the length of the lobes, sometimes shorter, broader, and hardly longer than the lobes.

HOUSTONIA PALMERI. *H. asperuloides* et *H. angustifoliæ* sat proxima, fere glabra; caulibus e radice perenni diffuso-ramosissimis gracillimis; stipulis parvis nudis; foliis lineari-filiformibus (semipollicaribus) pedunculis sparsis gracilibus adscendentibus (nunc pollicaribus) brevioribus vel æquilongis; calycis lobis subulatis tubo sæpius 2–3-plo longioribus; corolla (purpurea) hypocraterimorpha, lobis intus crebre albo-puberulis tubo dimidio brevioribus; seminibus paucis turgidis circumscriptione rotundis. — Coahuila, Mexico, in the mountains east and south of Sattillo, *Palmer*, 1880, no. 397, 398.

HOUSTONIA (EREICOTIS) FASCICULATA. Fruticosa, ultrapedalis, ramosissima; ramis rigidis foliosis, junioribus tetragonis hirtello-puberulis; stipulis brevissimis scariosis sæpius biacuminatis; foliis lariciformibus vel subulato-linearibus rigidulis glabris (lin. 4–3–1-longis) internodio parum brevioribus et in axillis plerumque copiosis; cymulis paucifloris; floribus parvis (lin. 2 longis) brevi-pedicellatis; corollæ tubo calycis lobis obtusiusculis subduplo et lobis suis parum longioribus; capsula ovali ab apice libero integro loculicida; seminibus in loculis 4–5 majusculis elongato-oblongis peltatis ventre vix concavis, testa læviuscula. — Southwestern border of Texas, at Presidio, *Bigelow* in Mexican Boundary Survey. Organ Mountains, New Mexico, *G. R. Vasey*, 1881, Coahuila in Mexico, near Parras and Monclova, *Palmer*, 1880, no. 404, 406. — Except for the narrow seeds, this is a much less anomalous *Houstonia* than is my *H. acerosa*, of the same region, and the two must go together into a section for which I incline to preserve De Candolle's name of *Ereicotis*, some species of which certainly have loculicidal dehiscence; and I doubt if the genus *Mallostoma* can be maintained.*

GALIUM ROTHROCKII. Facies *G. Wrightii*, Gray, pariter suffruticorum, erectum, sed glabrum, læve; foliis quaternis minoribus linearibus subcoriaceis eveniis mucronatis; panicula laxa floribunda; fructu parcius hirsuto. — S. Arizona, *C. Wright* (part of no. 1113), *Rothrock* (no. 675, not mentioned in his volume, the fruit hardly formed); *Lemmon*, 1881, with good fruit; New Mexico, *Rusby*.

VERNONIA ERVENDBERGII. *Lepidaploa*, herbacea, glabella; caule ramoso; foliis lanceolatis vel oblongo-lanceolatis serrulatis supra scabris; capitulis laxe corymboso-cymosis sparsis longiuscule pedun-

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* HOUSTONIA (EREICOTIS) ACEROSA, first published as *Hedyotis* (*Ereicotis*) *acerosa*, in Pl. Wright, i. 81, has been referred to *Mallostoma* by Hemsley, in Biol. Centr. Amer. ii. 31, notwithstanding the note in Gen. Pl. The roundish seeds have a deep but small ventral excavation. *Houstonia humifusa*, Gray, Proc. Am. Acad. iv. 314, as Hooker remarks, has the stipules sparsely ciliate with setiforum teeth: no. 400–403 of Palmer's 1880 coll. are forms of it.

culatis 25–40-floris: involucro lin. 3–4 alto subcampanulato, bracteis gradatim imbricatis acutis vel apiculato-acuminatis; pappi setis lin. 3 longis, squamellis exterioribus diam. achenii haud excedentibus. — *V. liatroides*, Gray in coll. Ervendb., Proc. Am. Acad. v. 181, excl. syn. & pl. Coult. — Mexico; near Tantoyuca, *Ervendberg*. Near Monclova, *Palmer*, no. 750. Apparently also near Monterey, *Gregg*. *V. liatroides*, DC. (which, according to Schultz Bip., is also his *V. Ehrenbergiana*), has much more numerous, smaller, and fewer-flowered heads, and mostly broader leaves more rugosely veiny beneath.

Vernonia Schaffneri. *Lepidaploa*, herbacea, scaberula, 1–2-pedalis: foliis ovalibus oblongisque (obtusis) basi acutis; capitulis paucis subumbellato-cymosis longiuscule pedunculatis circa 40-floris; involucro hemisphærico lin. 4–5 alto, bracteis pluriseriatis oblongis obtusis, extimis minimis nunc acutis; pappi setis lin. 3 longis squamellis brevibus conspicuis circumdatis. — Mexico, San Louis Potosi, in the mountains near Morales, *Schaffner*, no. 347. Coulter's no. 229 may be a form of the same species.

Vernonia Greggii. *Lepidaploa*, herbacea, subpubescens; caule sat robusto; foliis oblongo-lanceolatis mox scabris acutis denticulatis; capitulis paucis sparsisve longiuscule pedunculatis circa 50-floris; involucro hemisphærico lin. 5 alto, bracteis pluriseriatis oblongo-lanceolatis acutis vel acuminatis; pappi setis lin. 3–4 longis et squamellis angustissimis lineam longis. — Northern Mexico, *Gregg*, 1848–9, no. 102.

Var. Palmeri. Capitulis majoribus; squamellis pappi validioribus brevioribus. — Lerios, a mountain district east of Saltillo. *Palmer*, no. 753.

Stevia Lemmoni, Gray in Syn. Fl. ined., is fructicose, puberulent, leafy up to the dense clusters of very numerous heads: leaves all opposite, linear-oblong, obtuse, thinnish, obscurely triplinerved: involucre somewhat viscid-pubescent: flowers apparently white: pappus a cupulate and almost entire short crown. — S. Arizona, in the Santa Catalina Mountains, *Lemmon*, 1880.

Stevia Plummeræ, Gray, l. c., is herbaceous, puberulent and the bright green foliage almost glabrous, leafy up to the dense clusters of heads: leaves commonly opposite, oblong-lanceolate or broader, acute, incisely serrate, very conspicuously nervose-veiny and reticulated, hardly punctate: flowers deep rose-purple: pappus of 4 broad and truncate fimbriate-denticulate paleæ. — S. Arizona, in the Rucker Valley, Chirricahua Mountains, *Mr. & Mrs. Lemmon*, 1881. Also on the divide of the Mogollon Mountains, New Mexico, *Rusby.* — A very pretty and distinct species of Stevia, which may appropriately bear the name of one of the discoverers, Mrs. Lemmon, botanically still best known by her maiden name of Plummer, having shared the labors and privations of her husband in the arduous exploration of which this is one of the fruits. These two species are the only ones of the genus yet known as peculiar to the United States, the three others ranging through Mexico.

EUPATORIUM PAUPERCULUM. E grege *E. ageratoides*, glabrum, ultrapedale; foliis ovato-lanceolatis; foliis (pollicaribus) ovato-lanceolatis basi sæpius rotundatis obtusiuscule serratis sat petiolatis; ramis floridis brevibus cymis oligocephalis terminatis paniculam foliosam referentibus; capitulis 25-floris parvis (lin. 2 longis); involucri bracteis lanceolatis acutiusculis dorso hirto-puberulis; corollæ albæ lobis extus parce tenuiterque barbellatis mox nudis; pappo albo molli, setis barbellulatis. — On dripping rocks in the Santa Rita Mountains, S. Arizona, *Pringle.*

EUPATORIUM FENDLERI. *Brickellia Fendleri*, Gray, Pl. Fendl. 63, Pl. Wright. ii. 73. This proves to be an *Eupatorium*, with 5-angled but not rarely 6-nerved akenes, or sometimes one or two of the nerves at the angles are double. It has recently been collected in Arizona as well as New Mexico, by *Greene*, *Lemmon*, and *Rusby.*

EUPATORIUM (PHANEROSTYLIS: styli rami sursum incrassati petaloideo-ampliata, corolla sursum ampliata 5-lobo) COAHUILENSE. Humilis, e basi perenni multicaulis, diffusum, viscido-puberulum; foliis plerisque oppositis ovatis obtusis parce dentatis longe petiolatis; pedunculis terminalibus elongatis monocephalis; capitulo semipollicari plurifloro; involucro imbricato pauciseriali, bracteis linearibus, extimis laxis herbaceis, interioribus paucistriatis; achenio lineari; pappo e setis circiter 24 sat validis albidis barbellulatis; corolla cum stylis insignioribus longe exsertis aut albis aut carneis. — Northern Mexico, in the Sierra Madre, south of Saltillo, Coahuila, *Palmer*, no. 453.

BARROETEA SUBULIGERA, Gray, Proc. Am. Acad. xv. 29. *Bulbostylis subuligera*, S. Schauer in Linn. xix. 718. No. 452 of Palmer's North Mexican collection, 1880, abundantly gathered at Soledad, "a section of low mountains with a few oaks, 25 miles southwest from Monclova in Coahuila." The heads well accord with one from an original specimen. But the plant of Aschenborn is said to be "fruticulus pedalis," with rameal leaves 9 lines long and a petiole of 2 lines, the upper still smaller. Palmer's specimens are taller than this, and still herbaceous, but want the base, which is probably lignescent; are widely and freely branching; and the leaves, even the largest (about an inch and a half long), have a petiole of two lines at most, commonly shorter. The akenes are well flattened, sharp-edged, one face slightly convex and the other concave, the latter with a midnerve, the pericarp very thin. The heads in this, as also in *B. setosa*, are all erect. But in the herbarium of M. Boissier is a specimen from herb. Pavon, which, so long as there is no evidence that the forms run together, must be taken as a third species of the genus, and the original character will have to be modified a little in respect to the nervation of the akenes: —

Barroetea Pavonii. Herbacea; foliis ovatis membranaceis basi lata truncata vel subcordata arcte sessilibus argute dentatis, dentibus setigeris; capitulis laxe paniculatis in pedunculo gracili nutantibus; involucri (lin. 4 longi) bracteis fere scariosis lanceolatis mucronato-acutatis; acheniis latiusculis plano-compressis, uno latere 3- altero 1–3-nervato. — Mexico, herb. Pavon, nunc Boissier, sub nom. "Eupatorium setiferum" and "E. cuspidatum." Char. from notes taken in herb. Bossier and two capitula. In form the involucral bracts resemble those of *B. setosa*.

Brickellia odontophylla. Sat elata, puberula; caulibus vel ramis simplicibus; foliis alternis membranaceis petiolatis grosse crenato-dentatis cordatis vel subcordatis, sinu lato aut truncato aut medio breviter cuneato-decurrente, venis haud reticulatis; capitulis racemosis secundis pendulis iis *B. secundifloræ* (forma *B. Cavanillesii*) similibus; involucri glabri bracteis omnibus acutis. — Coahuila, Mexico, in the Sierra Madre south of Saltillo, *Palmer*, no. 442. Leaves with lamina an inch or two long, thin; lower obtuse and almost as wide as long, some of them with more tapering apex.

Brickellia Pringlei. Inter *B. cylindraceam* et *B. thyrsifloram*; caulibus herbaceis strictis bipedalibus puberulis superne hirsutulis; foliis brevi-petiolatis oblongo-lanceolatis acutis basi obtusis subserratis fere coriaceis trinervatis eximie reticulatis scabro-puberulis; thyrso e ramis floridis brevibus oligocephalis laxo folioso; capitulis vix pedunculatis plusquam 20-floris; involucro pluriseriatim imbricato, bracteis glabris, intimis lanceolatis acutis, exterioribus ovatis rotundisque parum mucronatis in bracteolas pedicellum imbricantes transeuntibus. — S. Arizona, in cañons of the Santa Catalina Mountains, April, 1881.

Brickellia Lemmoni. Foliis priori capitulis et inflorescentia *B. betonicæfolia* sat affinis, cinereo-puberulis; caulibus gracilibus ultrapedalibus thyrsoideo-floribundis; foliis submembranaceis lanceolatis basi acutis sessilibus vel in petiolo brevissimo marginato attenuatis minus reticulatis; capitulis plerisque breviuscule ac graciliter pedunculatis 10–12-floris; involucri pauciseriati bracteis sensim acutatis, intimis linearibus, extimis ovato-lanceolatis. — Rucker Valley in the Chiricahua Mountains, S. Arizona, *Lemmon*, 1881.

BRICKELLIA CYLINDRACEA, Gray & Engelm., var. LAXA. Forma caule aut simplici aut laxe ramoso; capitulis minoribus aperte paniculatis nunc brevissime nunc exserte pedunculatis; foliis ramealibus petiolatis. — Southwestern part of Texas, at Georgetown and Bluffton, *Palmer*.

BRICKELLIA GRANDIFLORA, Nutt., var. PETIOLARIS. Forma gracilis, sat elata; foliis hastato-deltoideis nunc longe sensim acuminatis petiolo gracillimo (1–2 pollicari) paullo parumve longioribus. — Mountains of S. Arizona, *Lemmon*.

BRICKELLIA FRUTESCENS. Frutex humilis; ramis divaricatis capitulis subsolitariis terminatis; foliis omnibus alternis parvis (lin. 3–5 longis) spathulatis integerrimis eveniis; involucro circa 20-floro, bracteis obtusiusculis; acheniis glabellis; pappi setis minutissime crebreque serrulatis. — Tantillas Cañon, near the borders of San Diego Co., but within Lower California, *Palmer*, 1875, with heads undeveloped. Mountain Springs, San Diego Co., *G. R. Vasey*, 1880, in flower. And, according to Dr. Vasey, also collected by the late *Sutton Hayes* in the same district.

KUHNIA SCHAFFNERI. Humilis, glaucescens, fere glabra; radicibus tuberosis; caulibus brevibus decumbentibus foliis sublinearibus oblongisve integerrimis parvis (lin. 3–6 longis) crebre instructis, fertilibus pedunculo adsurgente nudo scapiformi (ultra-spithamæo) monocephalo terminatis; capitulo ultra-semipollicari. — Valley of Mexico, *Schaffner*. Sent by the discoverer, without name, to Dr. Cosson of Paris.

LESSINGIA GLANDULIFERA. *L. Germanorum* sat proxima; caule erecto ramosissimo; ramis rigidis ramulisque foliis parvis crebris nunc quasi imbricatis coriaceis rigidis glabris margine pl. m. glanduliferis instructis; involucro magis turbinato. bracteis etiam sæpius glanduliferis: glandulis modo *Calycadeniæ* claviformibus. *L. Germanorum* et *L. ramulosa*, var. *tenuis*, pro parte, Gray, Bot. Calif. i. 307, etc. — *L. Germanorum*, Less., of which I have an original specimen, is whitened when young with an appressed tomentum, even up to the involucre; the bracts of which are less unequal, more foliaceous, and, like the sparse and softer leaves, wholly destitute of the nail-headed glands which conspicuously appear on most specimens of the species now recognized, though sometimes they are few and small. The corollas are plainly yellow, more so than in dried specimens of *L. Germanorum*, which according to Chamisso are saffron-colored. The original species we have only from the neighborhood of San Francisco. *L. glandulifera* occurs from Monterey to San Diego, Owens Valley, San Bernardino, &c. Fine specimens from the latter district, collected by the Brothers Parish and Mr. Pringle, have directed my attention to the species, which I had confounded with two others.

GRINDELIA COSTATA. Elata, glabra, lævis; ramis gracilibus monocephalis; foliis fere membranaceis lanceolatis acutis serrulatis basi auriculis breviter adnato-decurrentibus semiamplexicaulibus; capitulo hemisphærico semipollicari; involucri bracteis brevibus subulatis demum squarroso-recurvis modo *G. squarrosæ;* acheniis (lineam longis) lævibus lunato-gibbosis vel incurvis circa 10–costatis, costis plerisque crassis (valleculis angustissimis) obtusis, ventrali cariniformi; areola epigyna parvula. — Northern Mexico, near Juraz, in Coahuila, 100 miles north of Monclova, *Palmer*, no. 472.

GRINDELIA SUBDECURRENS, DC., is a species which should likewise be well distinguished by the akenes: these in De Candolle's specimens are at maturity so turgid as to be globular, are without ribs and almost without angles, the slightly depressed terminal areola rather large. Specimens which have been referred to it, with immature fruit more prismatic, may probably belong to *G. squarrosa.*

GRINDELIA ARIZONICA. Gray, as yet unpublished (to which belongs *G. microcephala*, Rothrock in Wheeler Rep. 141), of which ripe fruit is still wanting, appears to include no. 467 of Palmer's North Mexican collection.

ACAMPTOPAPPUS SHOCKLEYI. Frutex humilis, ab *A. sphærocephalo* differt capitulis majoribus hemisphæricis in pedunculo gracili ramos patentes terminante solitariis *radiatis;* ligulis circiter 12 (oblongis semipollicaribus luteis); involucro minus imbricato; pappo achenio paullo longiore. — Western Nevada, near Candelaria, Esmeralda Co., *W. S. Shockley.*

BIGELOVIA INTRICATA. Suffrutescens, divergenti-ramosissima, glaberrima, parce squamoso-foliata; ramulis gracillimis monocephalis; foliis crassiusculis subulatis sæpius mucrone apiculatis, majoribus semipollicaribus, ramulinis minimis squamiformibus; capitulis (lin. 3–4 longis) 12–15-floris; involucro campanulato, bracteis sat numerosis spiraliter 3–4-seriatim imbricatis subchartaceis (albidis nervo viridulo) acutis inappendiculatis, extimis lato-lanceolatis brevibus, intimis linearibus; corollæ lobis brevibus ovatis; styli appendicibus lineari-lanceolatis parte stigmatifera longioribus; acheniis teretibus pluristriatis hirsutulis pappo dimidio brevioribus. — S. E. California, in the Mohave desert, at Lancaster station, *Parry*. A notable species, having the very short corolla-lobes of the section *Chrysothamnopsis*, along with the involucre of the *Euthamioideæ* division of the *Aplodiscus* section.

BIGELOVIA ALBIDA, Marcus Jones in herb. *Chrysothamnus*, fruticosa, 2–3-pedalis, fastigiato-ramosa, subglaber, glutinosa; ramis ad apicem usque (sæpius fasciculatim) foliosis; foliis fere filiformibus (pollicaribus) mucronatis; capitulis cymoso-confertis semipollicaribus 5-floris; involucri bracteis lanceolatis subcoriaceis, exterioribus sursum subfoliaceis subpatentibus in acumen aristellatum productis, intimis papyraceis muticis; corolla "alba!" (ut videtur ochroleuca), lobis linearibus; antheræ appendicibus brevissimis obtusissimis; styli appendicibus lineari-filiformibus parte stigmatifera 2–3-plo longioribus; acheniis villosulis. — In alkaline soil, Wells, Nevada, *Marcus Jones*, August, 1881.

ASTER (ORTHOMERIS) STENOMERES. *Ianthe*, *A. scopulorum* (*Diplopappus alpinus*, Nutt.) proximus; caulibus gracilibus subpedalibus; foliis viridibus angusto-linearibus longioribus vix marginatis; involucro lato, bracteis parum biseriatis tenuioribus minus inæqualibus linearibus, junioribus laxe pubescentibus; ligulis ultra-semipollicaribus. — Rocky Mountains of Montana and Idaho, *Burke*, *Watson*; collected by the former many years ago, by the latter in 1881 at Battle Camp.

ASTER (ORTHOMERIS) PALMERI. *A. spinoso* aliquanto affinis, caule frutescente capitulisque *Feliciis* Capensibus similis, glaber; ramis herbaceis e caule lignoso 4-pedali paniculato-ramosissimis *Baccharidis* modo striato-angulatis; foliis integerrimis angustissime linearibus leviter uninerviis, ramulorum parvis obtusis; capitulis paniculatis sparsis lin. 3 longis; involucri campanulati bracteis imbricatis erectis oblongis obtusis rigidulis, dorso versus apicem viridulo, marginibus scariosis; receptaculo fimbrillis acheniis angustis subteretibus hirsuto-sericeis dimidio brevioribus onusto; ligulis 8–10 brevibus albis; fl. disci circiter 20. — S. Texas, at Corpus Christi Bay and on the Rio Grande at Eagle Pass, September and December, 1879. *Palmer*, no. 509, 516. This militates against the West Indian genus, *Gundlachica*, of Proc. Am. Acad. xvi. 100.

Aster imbricatus. Walp. Rep. ii. 574. This is the name, by transference, of the Chilian species named by Nuttall *Tripolium imbricatum*. And it may here be noted that it is the original *Tripolium conspicuum*, Lindl. in DC. Prodr. v. 254, founded on specimens of Bridges and Bertero; a plant of rather rigid and strict habit, perhaps perennial, with comparatively large solitary heads, and a "turbinate" involucre of firm pluriserially imbricated bracts, the outermost ovate and ovate-lanceolate, the inner mostly acute. It is quite different from the common and wide-spread annual species which has been taken for it.

Erigeron dryophyllus. *Euerigeron*, subcinereo-pubescens; radice perenni; caule pedali parce ramoso; ramis apice nudis monocephalis; foliis membranaceis obovatis lyrato-pinnatifidis sinuatisve in petiolum alatum attenuatis, ramealibus lanceolatis subintegris; involucri bracteis subulatis; ligulis 80–90 longe exsertis lin. 3 longis albis purpureo tinctis; acheniis parce hispidulis ad margines tantum nervatis; pappo fere simplici, setulis exterioribus paucis exiguis. — Northern Mexico, in the mountains at Guajuco, N. Leon, southeast of Monterey, *Palmer*, no. 495.

Erigeron Pringlei. Cæspitosus e caudice crasso multicipiti, pygmæus, fere glaber et lævis; caulibus floridis simplicibus erectis vel patentibus gracilibus inferne foliatis monocephalis; foliis radicalibus pinnatim 3–5-fidis in petiolum longe attenuatis, lobis brevibus oblongis acutis, caulinis angusto-linearibus; involucro glabro; ligulis 25–35-violaceis. — Crevices of rocks on the Santa Rita Mountains at the elevation of 9000 feet, S. Arizona, *Pringle*.

Erigeron Muirii. Affinis *E. grandifloro*, Hook., differt insigniter lana gnaphalioidea mollissima longa herba tota vastiente; caulibus spithamæis monocephalis; foliis plerisque spathulatis; involucri bracteis sursum attenuatis; ligulis albis; pappo externo multisquamellato conspicuo. — Cape Thompson, Alaska, *John Muir*, 1881. The most interesting and apparently the only new species of an extensive and truly valuable collection made by Mr. Muir in a recent searching-cruise which he accompanied, and which extended to Wrangel Island. The plant seems to have been abundant, for it occurs in the collection under three numbers. The head, style, rather scanty main pappus, &c., are very much as in *E. grandiflorus*, especially of the var. *lanatus;* but of that the pubescence is villous, except at the head, towards the base of the plant varying to hirsute: in this the whole plant is densely clothed with long and soft cottony wool, quite in the manner of *Gnaphalium*, and the short outer pappus is very conspicuous.

Baccharis sarothroides. *B. Emoryi* affinis, scoparia, microphylla; foliis linearibus integerrimis, ramulinis minimis; capitulis laxe paniculatis minoribus paucifloris; pappi fl. masc. setis apice nudis, fl. fœm. demum lin. 3 longis. — Southern borders of California, San Diego Co., near the old Mission station, the boundary monument, &c., *Sutton Hayes*, *Palmer*. This is one of the species with soft elongating pappus in fruit, which has been somewhat confounded with *B. Emoryi*, and also with *B. sergiloides*, which belongs to another section.*

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* The North American species of *Baccharis* I now understand in this wise, arranging them in four groups.

1. Pappus of the fertile flowers very copious, pluriserial, elongated in fruiting, fine and rather soft: akenes 8–10-costate: stems somewhat simple and herbaceous above the woody base: leaves linear, 1-nerved. — To this group belong *B. juncea* of S. Brazil, of which I have not seen akenes, and *B. Seemanni*, Gray, of Mexico, only that the latter appears to have 5-nerved akenes.

B. Wrightii, Gray, Pl. Wright, i. 101, & ii. 83. W. Texas to S. Colorado and Arizona.

B. Texana, Gray, Pl. Fendl. 75, & Pl. Wright, l. c. Texas.

2. Pappus of the fertile flowers less copious, conspicuously elongating in fruit, soft and fine, mostly flaccid and bright white: akenes 10-nerved. These are branching shrubs, with numerous glomerulate or paniculate heads, the leaves sometimes incisely lobed or angulate dentate, but not serrate.

* Atlantic species.

B. halimifolia, L. Coast of New England to Texas; also in Cuba.

B. glomeruliflora, Pers. North Carolina to Florida near the coast; also Bermuda.

B. salicina, Torr. & Gray. *B. salicifolia*, Nutt. Colorado, east of the mountains, to W. Texas. I have seen few specimens that belong to this species. Its leaves are from oblong to linear-lanceolate, rarely entire; heads or glomerules of two or three heads pedunculate; involucre of both sexes campanulate (nearly 3 lines long), of mainly ovate and acutish bracts.

B. angustifolia, Michx. Brackish marshes, from S. Carolina and Florida to Texas.

* * Pacific species.

B. pilularis, DC., including *B. consanguinea*, DC. Pacific coast from Monterey to Oregon.

B. Emoryi, Gray, Bot. Mex. Bound. 83. S. California from Los Angeles Co., and through the interior country well into Arizona and the southern part of Nevada and Utah. Originally described only from upper branches; some specimens of it have been referred to the preceding, others to *B. salicina*.

PLUCHEA (BERTHELOTIA) BOREALIS. *Tessaria borealis*, Torr. & Gray (§ Phalacroclıne, Gray, Pl. Wright), &c. *Berthelotia lanceolata*, DC., being referred by Bentham to Pluchea, carries with it the present plant. The near affinity of the two, as well as the subcaudate anthers, I had noticed in Pl. Wrightianæ, i. 102, but I did not carry out the conclusion on account of the stoutness of the pappus-bristles. — *Tessaria*, Ruiz & Pav., considering that the species are exclusively South American, may be retained, and characterized by the narrow heads and the long villosity of the small receptacle.

ANTENNARIA FLAGELLARIS. Capitula *A. dimorphæ* sed minor, floribus paucioribus; caudice parvo simplici emittente flagellis scapiformibus gracillimis nudis (spithamæis) propagine mox radicante et

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From the variations in the size of the heads and a difference in male involucres, this may comprise two species.

B. SAROTHROIDES, Gray, *supra*. So far as known, this is confined to S. California along and near the Mexican frontier.

* * * Of New Mexico, Arizona, and Mexico; the branches terete and lightly striate (not striate-angled as in the preceding and in most of our species), minutely pruinose-roughened.

B. PTERONIOIDES, DC. Prodr. v. 410. *B. ramulosa*, Gray, Pl. Thurb. 301, & Bot. Mex. Bound. 84. *Aplopappus ramulosus*, DC. *Linosyris* (*Aplodiscus*) *ramulosa*, Gray, Pl. Wright. The specimen in the Candollean herbarium appears to be this rather wide-spread and peculiar Mexican species.

3. Pappus of the fertile flowers not longer than of the male, even in the fruit not surpassing the style, therefore not elongating in age, rather rigid and scanty: akenes 10-nerved, but the intermediate nerves sometimes indistinct: fertile corollas regularly and acutely 5-toothed: receptacle bearing some chaffy scales similar to involucral bracts among the outer flowers, becoming hemispherical or conical when these are numerous: branches herbaceous from a woody base; the fruitful ones bearing sparing small leaves, or naked, and paniculate small heads.

B. SERGILOIDES, Gray in Pacif. R. Rep. iv. 101, & Bot. Mex. Bound. 83, also Bot. Calif. i. 333, but there mixed with *B. sarothroides*, &c. Desert of S. E. California to Nevada and adjacent borders of Nevada and Utah.

4. Pappus of the fertile flowers not flaccid, little if at all elongated in fruit, mostly not copious: akenes only 4–5-nerved.

* Scabro-puberulent or pubescent, not glutinous: fruiting pappus manifestly surpassing the style: heads loosely paniculate: bracts of the involucre scarious with a green or greenish back or centre, acute or acuminate: stems herbaceous from a more or less woody base.

B. BRACHYPHYLLA, Gray, Pl. Wright, ii. 83. S. Arizona to the borders of California. Very minutely puberulent.

monocephalo terminatis; foliis omnibus angusto-linearibus. — *A. dimorpha*, var. *flagellaris*, Gray, in Wilkes Exped. xvii. 366. — Washington Territory and eastern part of Oregon, *Pickering* and *Brackenridge*, *Cusick*, *Howell*. A peculiar species of the marked section to which *A. dimorpha* belongs. Incomplete specimens were referred to that species, on the strength of Nuttall's description, from which it would seem that his female plant might almost be of this species. And the following proves to be a third species of this section.

ANTENNARIA STENOPHYLLA. Stolonibus flagellisve ut videtur nullis; caulibus gracilibus 3–6-pollicaribus foliosis foliisque angusto-linearibus acutatis elongatis argenteo-lanatis; capitulis 2–4 ad apicem nudum caulis capitatim congestis; involucro utriusque sexus lin. 2–3

B. PLUMMERÆ, Gray, Proc. Am. Acad. xv. 48, &c. Mountain ravines back of Sta. Barbara and Sta. Monica. *Miss Plummer* (now *Mrs. Lemmon*), *Parish*.

* * Glabrous or nearly so, smooth, often glutinous: fruiting pappus slightly if at all surpassing the style.

+ Bracts of the 15–30-flowered involucre rather narrow and of firm texture, with green centre or costa: leaves rather small and rigid, serrate with rigid or spinulose teeth.

B. THESIOIDES, HBK. Includes *B. ptarmicæfolia*, DC. A common Mexican species, collected in S. Arizona by *Wright*.

B. BIGELOVII, Gray, Bot. Mex. Bound. 84. First collected in Arizona and New Mexico by *Bigelow*, *Wright*, and *Thurber*, recently by *Lemmon* and *Rusby*.

+ + Bracts of the many-flowered involucre rather narrow, thin and pale but with greenish centre: heads corymbosely cymose: receptacle hemispherical or broadly conical!

B. DOUGLASII, DC., including *B. Hænkei*, DC., which came from Monterey, California, not Mexico. An herbaceous species, wholly Californian.

+ + + Bracts of the many-flowered involucre broad (outer ovate), thin-chartaceous, rather dry, with narrow scarious margins (at least the inner) yellow or tawny: stems very leafy up to the corymbosely cymose inflorescence: leaves lanceolate, willow-like.

B. GLUTINOSA, Pers. A name to be adopted if this is indeed the Chilian species, as I suppose. It is certainly both *B. cærulescens* and *B. Alamani* of De Candolle, and probably has other names. It is a tall species, herbaceous from a more or less woody base, common from S. California to S. W. Texas and through Mexico.

B. VIMINEA, DC. A Californian species, which extends from Monterey to San Bernardino Co., is a true shrub, 6 to 12 feet high, with shorter and more entire leaves than the foregoing, bearing smaller clusters of larger heads, terminating short lateral branchlets. According to Messrs. Parish Brothers it blossoms at the end of winter or in early spring; while the foregoing blossoms in autumn.

longo, bracteis omnibus ovatis oblongisve obtusiusculis brunneis vel masculis internis apice albo; setis pappi fl. masc. sursum parum barbellulatis haud clavellatis. — *A. alpina?* var. *stenophylla*, Gray, in Wilkes Exped. l. c. — Spipen River, Washington Terr., *Pickering* and *Brackenridge*. Union Co., Oregon, on high hills, *Cusick*.

GNAPHALIUM WRIGHTII. *G. microcephalo* peraffine; ramis diffusioribus; foliis latioribus plerisque spathulatis basi nunquam adnato-productis; involucri bracteis griseo-albis obtusis, interioribus apiculato-acutatis. — *G. microcephalum*, Gray. Pl. Wright, i. & ii., non Nutt. — Common from S. Arkansas and W. Texas to New Mexico. Also no. 419 of Parry and Palmer's collection from San Luis Potosi, Mexico, which has been referred to *G. canescens*, DC.; but, from the character, that species is better represented by no. 433½ of the same collection.

ADENOCAULON. To the remarks in Proc. Am. Acad. viii. 653, the following correction and addition should be made. An attentive examination of all the species shows that the basal auricles of the sagittate anthers are manifestly produced into a slender acumination or small tail, the adjacent ones connate. And the genus is so thoroughly congruous with *Carpesium*, which is anomalous in the *Eninuleæ*, that the two may well be associated in the Inuloid subtribe *Adenocauleæ*.

MICROPUS AMPHIBOLUS. *M. Californico* proximus, differt floribus fœmineis 9–10 in receptaculo oblongo subimbricatis, bracteis fructiferis tenuioribus (maturis chartaceis) parum latioribus, appendice ovata hyalina majore primum arcte inflexa demum porrecta; floribus sterilibus pappo paucisetoso instructis. — California, no. 416 of *Kellogg & Harford's* distribution; and Walnut Creek near Martinez, *Brewer*, 1860-62. — I wish to call attention in California to this plant, which has been confounded with *Micropus Californicus* and with some other *Filagineæ*. Its characters are such as really to give some color to the merging of *Stylocline* in *Micropus*, the female flowers, about ten in number, being spirally inserted on a somewhat elevated though hardly columnar receptacle, the scarious hyaline apical appendage to the bract (which all the species possess) being larger in proportion to the bract, indeed almost of its length in anthesis, and then inflexed, afterwards horizontal, and the almost mature fructiferous bracts comparatively thin and soft, so that it approaches *Psilocarphus*. Moreover the few staminate flowers are subtended by linear deciduous paleæ, and provided with a few pappus bristles. The organic apex of the ovary, though lateral, is close to the summit. Transitional though it be, I cannot refer the plant to *Stylocline*, nor suppress that genus without also suppressing *Psilocarphus*.

PLUMMERA, Nov. Gen. *Compositarum.*

Capitula heterogama, pauciflora; floribus radii fœmineis ligulatis 2–5, disci masculis 6–8. Involucrum obpyramidatum, cupuliforme, cartilagineo-coriaceum, duplex; exterius e bracteis 4 ovatis oblongisve obtusis dorso carinatis ultra medium usque sæpius coalitis; interius e bracteis totidem alternantibus vix brevioribus liberis obovato-cuneatis apice lato rotundato subscariosis. Receptaculum planum nudum. Corollæ radii lato-cuneatæ, trilobæ, sensim in tubum brevem angustatæ; disci tubuloso-infundibuliformes, breviter obtuseque 5-dentatæ, extus crebre glanduloso-pubentes, tubo proprio brevi crassiore. Antheræ basi obtusæ. Stylus fl. disci apice brevissime bifidus, ramis haud stigmatiferis, apice depresso-dilatato semi-peltato: ovarium inanum gracile. Achenium fl. radii turgidum, obovatum, ecostatum, sursum pilis tenuissimis villosum, areola epigyna parva parum depressa: pappus nullus.

Plummera floribunda. Herba ut videtur biennis, bipedalis, superne corymboso-ramosissima, foliosa, subglabra, odore et sapore amaro-aromatica; foliis omnibus tenuiter 1–3-ternatim partitis, modo *Helenii* et *Actinellæ* impresso-punctatis; capitulis parvis perplurimis fastigiato-cymosis plerisque pedunculatis; floribus aureis. — Apache Pass, S. Arizona, *Mr. & Mrs. Lemmon.* Dedicated to the latter, under the name which she until recently bore; the partner of her husband in the severe labors and privations of Arizona exploration, and in the honor of this and of many other interesting discoveries. The natural affinity of this plant may rather be with *Actinella* in the *Helenioideæ;* but the essential characters are wholly those of the *Helianthoideæ-Millerieæ.*

DUGESIA, Nov. Gen. *Comp.-Melampodiearum.*

Capitula heterogama, radiata; fl. radii 8–12 fœmineis, disci plurimis hermaphrodito-sterilibus. Involucrum latum, duplex; exterius foliaceum, e bracteis 6–8 obovatis oblongisve patentibus; interius e bracteis numerosioribus oblongis membranaceis erectis. Receptaculum planum; paleis angusto-linearibus scariosis planis apice dilatato subherbaceis flores steriles subtendentibus, exterioribus ab acheniis et bracteis involucri subtendentibus omnino liberum. Corollæ radii ligula plana cuneato-oblonga apice 2–3-fida e tubo brevi; disci fere

Silphii, stylus sterilis *Silphii*, vel summo apice bifida: ovarium inane. Achenia obovata, crassa, obcompresso-turgida, dorso subconvexo uninervia, ventre subangulata, costa prominente superne in dentem crasso-subulatum rigidum porrectum desinente, marginibus dentato-alatis (nempe ala sinuato-incisa nunc pluripartita, lobis summis cartilagineis auriculiformibus forte ad pappum referentibus), basi nec bractea sua involucri nec paleis internis adnata.

Dugesia Mexicana. Herba humilis e radice perenni, facie *Chrysogoni*, foliis pinnatifidis hispidulis *Engelmanniæ* (sed plerisque oppositis), achenio dente interno instructo *Lindheimeræ*, sed *Silphio* potius affinis, achenio crasso (maturo tuberculato-scabro) schizoptera insignis. — *Lindheimera Mexicana*, Gray, Proc. Am. Acad. xv. 34; Hemsl. Bot. Centr. Am. ii. 141. San Luis Potosi, *Parry & Palmer;* but collected much earlier by *Dr. Schaffner.* This might seem to be referable to the obscure genus *Schizoptera* of Turczaninow; but the involucre and slender tube to the short ligules attributed to that genus indicate something different, perhaps more like *Guardiola.** — This genus is named in honor of Professor *Alfred Dugès*, of Guanaxuato, Mexico, a zealous zoologist, from whom we have recently received a collection of the plants of that part of the country.

Parthenium confertum. Herbaceum, pube adpressa substrigosa canescens et hirsutum; radice ignota forte perenni; caulibus 1–2-pedalibus sat validis subsimplicibus usque ad apicem foliosis; foliis circumscriptione obovato-oblongis bipinnatifidis, segmentis lobisque brevibus crebris obtusis, vel pinnatilobatis lobis paucies crenato-incisis; capitulis perplurimis corymboso-cymosis confertis; involucro canescenti-pubente; pappi paleis parvulis oblongis. — Plains of Coahuila, Mexico, near Parras, *Gregg*, 1847–9, *Palmer* (no. 648), 1880. Belongs to the section formed for *P. Hysterophorus* (but probably the root perennial), which species indeed approaches it in a canescent and simpler-leaved variety (var. *lyratum*), of the same region, no. 316, *Wright*, no. 647, *Palmer*, &c. The present species, now confirmed by Palmer's specimens, was long ago collected by the late Dr. Gregg.

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* Chrysogonum Virginianum, L. It still appears that this is the only species of the genus, although a rather variable one. The akenes at maturity fall away from the receptacle, carrying the involucral bract behind and the bracts of two or sometimes three sterile flowers in front: so the genus belongs to the Parthenioid group, along with *Berlandiera*, *Engelmannia*, &c., and not with *Silphium*, where Bentham placed it, having combined it with *Moonia*, Arn. and taking the character in these respects from that truly distinct Indo-Australian genus.

Ambrosia pumila, the *Franseria pumila*, Nutt., and of Torr. & Gray, Fl. ii. 293, of which "we had not seen the fruit," nor had Nuttall, is a good *Ambrosia*, with muticous fruiting involucre. Occasionally two of these are connate at base, on which character Delpino founded his genus *Hemiambrosia*. The species is very closely related to A. canescens, namely *A. fruticosa*, var. *canescens*, Benth. Pl. Hartw. 17, of Mexico. But that is taller, more silvery-canescent, with narrower lobes to the leaves, slender-pedicelled sterile heads, and some small spines to the fruiting involucre; the latter character probably unreliable.

Rudbeckia montana. E grege *R. occidentalis*, procera, lævis, fere glabra; foliis pinnatifidis, summis pauci-laciniatis, lobis paucijugis lanceolatis, terminali majore nunc oblongo-ovato; ligulis nullis; disco primum ovoideo, fructifero cylindraceo 1–3-pollicari; acheniis cum pappo longius cupulato lin. 3–4-longo. — Rocky Mountains of Colorado; *E. Hall*, spec. cult. Elk Mountains, Colorado, *Brandegee*.

Rudbeckia Mohrii. *R. atrorubenti*, Nutt., per-affinis, ramosior, glaberrima; foliis minus rigidis angusto-linearibus viridibus; disco atro-fusco subgloboso; ligulis luteis; paleis receptaculi parum mucronatis; acheniis longioribus subcurvatis areola obliquo insertis; pappo profunde cupulato. — Margin of ditches and ponds near the Dead Lakes, not far from Iola, W. Florida, June 22, 1880, *Charles Mohr*. This has some affinity on the one hand with *R. nitida*, but is a much nearer relative of *R. atrorubens*, which is quite of this genus, and no *Echinacea*. Dr. Mohr collected these two peculiar species in the same district.

Gymnolomia triloba. Subglabra, ramosa; radice ignota; foliis alternis lato-ovatis trilobis basi truncata vel subcordata; involucri bracteis linearibus disco hemisphærico demum ovoideo brevioribus; receptaculo conico; acheniis glaberrimis subcompressis calvis. — On peaks of the Chirricahui Mountains, south of Rucker's Valley, Arizona, *Lemmon*.

Synedrella vialis. *Calyptrocarpus vialis*, Less. Syn. 221, & Linnæa, ix. 269. *Oligogyne Tampicana*, DC. Prodr. v. 629; Deless. Ic. Sel. iv. t. 38; Gray, Pl. Wright. i. 111. *Blainvillea Tampicana*, Hemsl. Biol. Centr.-Am. ii. 169. In Pl. Wright., above cited, I had noted the near relationship of this plant to *Synedrella* as well as to *Blainvillea*, and concluded that the wingless akenes mainly distinguished it from the latter genus. I had then seen no winged or margined akenes, and did not know that upon this plant was founded the

Calyptrocarpus of Lessing, which is characterized as having "achænium plano-obcompressum . . . . interrupte et anguste alatum." A tuberculate winged margin of this sort is manifest in some of the outer akenes of Texan and Mexican specimens. *S. peduncularis* of Bentham appears to be the connecting link between this species and *S. nodiflora*. The author would doubtless have added this third species, if he had noticed that the akenes of the disk as well as the ray are obcompressed and dorsally subtended by narrow flat chaff. And so De Candolle's *Oligogyne* is described. *Blainvillea* is quite different in these respects. But to *Blainvillea*, and certainly not to this species, belongs *B. biristata*, DC. (the *Galophthalmum Brasiliense* of Nees and Martius), of Brazil.

Viguiera lanata. Tomento denso pannoso candidissima, humilis e basi ut videtur lignescente; foliis plerisque subradicalibus crassis rotundatis fere integerrimis trinervatis basi nunc subcordatis petiolatis, caulis floridi alternis, superioribus nunc omnibus ad bracteas parvas spathulatis linearibusque reductis; involucri imbricati (semipoll. alti) bracteis linearibus tomentosis; ligulis plurimis ultra-semipollicaribus; acheniis undique sericeo-villosissimis; pappi paleis intermediis truncatis fimbriato-laciniatis aristis subulatis dimidio brevioribus. *Bahiopsis lanata*, Kellogg, Proc. Calif. Acad. ii. 35. — Cerros Island, Lower California, *Veatch*, *Street*, *Belding*. — Through the kind attention of Dr. Parry, we possess an original specimen of Dr. Kellogg's *Bahiopsis*, which is here characterized. It is quite different from the plant doubtfully named *Viguiera nivea*, Benth.? in the Botany of California, which, falling back to its earliest specific name, now becomes *V. tephrodes*. Nor is it the *Encelia nivea*, of Benth. Bot. Sulph. 27, which is still ambiguous. The original at Kew appeared to me destitute of pappus, and Bentham's note, in Gen. Pl. ii. 376, leaves it to be inferred that he saw none. There is a plant collected in Lower California by Lieutenant Belding which accords with Bentham's description, except that the leaves are alternate, and there is a very caducous pappus of two aristiform paleæ, but no intermediate squamellæ. The akenes, when known, will probably refer it to *Encelia* rather than to *Helianthus*. But it is to be noted that *Encelia nivea*, Benth., is said to come from San Quentin. Now the only San Quentin we know is on the Bay of San Francisco. But the plant at Kew was not recognized on inspection.

Leptosyne (Coreocarpus) Arizonica. Suffruticosa, ramosa; ramis floridis elongatis herbaceis gracilibus foliatis; foliis omnibus oppositis 3–5-partitis, segmentis linearibus plerumque integerrimis; capitulis laxe corymboso-cymosis breviuscule pedunculatis; involucro externo indistincto e bracteis 1–3 parvis, interno seu proprio e bracteis 6–8 ovatis biseriatis; annulo corollæ tubi barbato; ramis styli fl. herm. appendice subulato superatis; acheniis oblongis marginibus serie tuberculorum quasi alatis aut calvis aut aristis 1–2 tenuibus instructis (faciebus aut lævibus aut hirtello-muriculatis), intimis minus perfectis angustioribus immarginatis. — Near Fort Lowell, Arizona, along streams, *Lemmon*, 1880. Santa Catalina Mountains, *Pringle* 1881. — The delicate short awns of the akenes are either naked or sparingly denticulate, the denticulations spreading or some of them recurved. The minute cupule at the summit of the ovary and akene is within the base of the corolla, therefore an epigynous disk. — It is becoming evident that *Leptosyne*, DC., *Pugiopappus*, Gray (*Agarista*, DC.), and *Coreocarpus* with *Acoma*, Benth., must be combined into one genus, which is the counterpart on the western side of North America of *Coreopsis* on the eastern, and from which it is distinguished by its fertile ray-flowers and by the annulus of the disk-corolla. The latter is a peculiarity of the genus. *Leptosyne maritima*, as we have it in cultivation, occasionally develops a short paleaceous awn to each margin of the summit of the akene. *Pugiopappus* (of three described species) and *Coreocarpus* form good sections, and the latter approaches *Bidens*.

MADIA YOSEMITANA, Parry in litt. Inter sect. *Anisocarpum* et *Harpæcarpum*, pusilla, spithamæa; foliis linearibus integerrimis, summis alternis; capitulis solitariis longiuscule pedunculatis; floribus radii 5, ligulis brevibus, involucri bracteis apice brevissimo erecto, achenio semi-obovato parum falcato apice coronula parva setulis ciliolata instructo; disci 3 sterilibus intra cupulam 4-dentatam, pappo instructis e setis paucis parce barbellatis corollam æquantibus. — California, in damp moss at the foot of the Upper Yosemite Fall, *Parry*, June 1881.

LAGOPHYLLA GLANDULOSA. *L. ramosissimæ* proxima; indumento parco brevi; ramulis foliis præsertim superioribus bracteisque glandulis claviformibus obsitis; acheniis minus obcompressis, areola terminali minore. — California, in the Sierra Nevada from Auburn to near the Yosemite, *Lemmon*, *Mrs. Bidwell*, *G. R. Vasey*.

ACTINELLA VASEYI. E grege *A. Richardsonii;* radice ut videtur perenni; caule stricto pedali ramisque floridis fastigiatis foliosis; lobis foliorum angusto-linearibus; involucro campanulato (lin. 3½ alto), exteriore 8–9-lobato, nempe e bracteis ovato-oblongis ultra medium connatis; ligulis majusculis (lin. 4 longis); receptaculo convexo; pappi paleis oblongis sæpius obtusis enerviis corolla disci vix dimidio brevioribus. — New Mexico, in the Organ Mountains, *G. R. Vasey*, August, 1881.

ARTEMISIA PARISHII. *Seriphidium*, frutescens, 3–4-pedalis, tomento minutissimo undique canescens; foliis (plerisque sesquipollicaribus) aut linearibus integerrimis (lineam latis) aut inferioribus apice dilatato tridentatis; panicula ampla laxa, ramis gracilibus polycephalis; capitulis (lin. 2 longis) 6–7-floris; involucro campanulato; acheniis utriculatis glandulosis et pilis arachnoideis parce villosis. — Newhall, Los Angeles Co., and in Cajon Pass, California, Oct. 1881, coll. *S. B. & W. F. Parish.* It has the habit and ample paniculate inflorescence of *A. Palmeri.*

SENECIO LEMMONI. Frutescens, parum succulentus, ramosissimus, tomento arachnoideo parco mox delapso glaberrimus; foliis lanceolatis argute dentatis vel denticulatis (summis linearibus integerrimis), imis in petiolum marginatum attenuatis, superioribus basi auriculato-dilatatis amplexicaulibus, auriculis spinuloso-dentatis; ramis floridis apice nudis; capitulis pauciusculis longius pedunculatis; involucro parum bracteolato; ligulis circ. 12. — Near Camp Lowell and Sta. Catalina Mountains, S. Arizona, *Lemmon*, 1880 & 1881. Not much like any other North American species.

CNICUS ROTHROCKII. *C. Arizonicæ* similis, ramosior; caule foliisque glaberrimis lævibus, vel ramis nunc pilis crispulis parce pubescentibus; involucri bracteis primum laxe lanulosis. *C. Arizonicus*, var., Rothrock in Wheeler Rep. vi. 179. — Central and Southern Arizona, *Rothrock*, 1874, *Lemmon*, 1881.

HECASTOCLEIS. Nov. Gen. *Comp.-Mutisiacearum.*

Capitula uniflora: flos hermaphroditus. Involucrum cylindraceum, e bracteis pauciseriatis imbricatis angusto-lanceolatis subherbaceis rigidis cuspidatis. Receptaculum parvum nudum. Corolla fere coriacea, tubulosa, angusta, regularis, limbo haud ampliato in lacinias 5 æquales lineares mox recurvo-patentes fisso. Antheræ lineares, subcoriaceæ, basi in caudas sat longas nudas productæ. Stylus integer, apice stigmatico truncato parum emarginato. Achenium immaturum cylindraceum, glabrum. Pappus coroniformis, laciniato-dentatus, corneus. — Frutex ramosus, glaber; ramis rigidis foliosis; foliis alternis et in axillis fasciculatis coriaceis, caulinis lineari-lanceolatis plerumque cuspidato-mucronatis margine hinc inde spinuliferis sessilibus, floralibus ampliatis lato-ovatis iliciformibus venulosis margine spinulis gracilibus armatis capitula sessilia pl. m. glomerata fulcrantibus paululum superantibus; corolla albida.

Hecastocleis Shockleyi. — Very arid district, at Candelaria, Esmeralda Co., Nevada, *W. S. Shockley*. A remarkable addition to the few known North American *Mutisiaceæ*, to stand near *Ainsliæa*, but altogether *sui generis* and of peculiar habit. The generic name alludes to the separate enclosure of each flower in its involucre.

Crepis pleurocarpa. Inter *C. occidentalem* et *C. acuminatam* quasi media, pube minuta cinerea demum decidua; caulibus subaphyllis; foliis runcinato-dentatis incisisve; cyma paniculiformi laxa; capitulis angustis paucifloris; acheniis oblongis sursum haud attenuatis eximie alato-10-costatis pappo paullo brevioribus. — Head-waters of the Sacramento, above Strawberry Valley, on wet slopes of the mountains, at the altitude of about 7,500 feet, 1881, *Pringle*. The short and thick akenes, with at least ten narrow and very salient ribs, almost wings, separated by broad grooves, distinguish this species.

Lobelia Gattingeri. *L. appendiculatæ* sat similis; floribus minoribus (lin. 3 longis); calycis lobis haud ciliatis attenuato-subulatis fere inappendiculatis basi utrinque callo minimo instructis, fructiferis capsula brevioribus; pedicellis quandoque bracteolatis. — Middle Tennessee, in springy places of calcareous bluffs and in cedar barrens. *Dr. Gattinger*. No. 1637 of the distribution of A. H. Curtiss, under the name of *L. leptostachys*. Flowering May and August, from a monocarpic root.

Githopsis diffusa. Demum effuse ramosissima; ramis gracilibus; foliis parvis; calycis lobis lanceolatis (basi latioribus) corollam subæquantibus ovario præsertim capsula fere lineari arcte sessili subdimidio brevioribus; seminibus turgide oblongis. — On Cucamonga Mountain, S. California, June, 1881, *S. B. & W. F. Parish*. The capsule opens apically, as in the original species.* The blue corolla is only 2 lines in length.

Androsace Arizonica. E grege *A. occidentalis*, tenella; scapis debilibus decumbentibus radiisque umbellæ pauciforæ capillaribus elongatis; foliis phyllisque involucri consimilibus brevibus; calycis lobis foliaceis, fructiferis accrescentibus ovatis radiato-patentibus tubo

* Baillon's statement to the contrary is founded on a misapprehension, he evidently having taken a Texan *Specularia* for *Githopsis*. See Bull. Soc. Linn. Par. 304.

brevi lato capsula semiclaudente longioribus; corolla minima; seminibus paucis (5–6) sat magnis. — Santa Catalina Mountains, S. Arizona, *Pringle.* Mostly in fruit, April 19, 1881; earlier specimens may have a less inconspicuous corolla. *A. occidentalis* has been collected in the same mountains.

Gomphocarpus hypoleucus. *Asclepiadi lanuginosæ* (Mexicanæ) haud dissimilis; caule valido bipedali puberulo; foliis omnibus oppositis ovalibus brevi-petiolatis supra glabratis viridibus infra albo-tomentosis; pedunculis umbella multiflora longioribus; corolla viridula, segmentis ovali-oblongis (lin. 4 longis); cucullis atropurpureis carnosis erectis (antheris duplo longioribus) oblongo-ligulatis et basi hastatis sed lobis seu appendicibus triangulatis acutis arcte inflexis, facie interna haud fissa. — Santa Rita Mountains, Arizona, *Pringle.**

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* The following *Gentianeæ* are contributed by Dr. Engelmann: —

Erythræa nudicaulis, Engelm. Biennis, *E. Douglasii* proxima; caule humiliore erecto sursum laxe brachiato-ramoso; foliis infimis ovatis basi breviter contractis rosulatis, caulinis paucis lineari-lanceolatis; floribus paucis longe pedunculatis; calyce tubum corollæ vix æquante; lobis corollæ oblongis obtusis planis tubo paullo brevioribus; antheris lineari-oblongis; stylo ovario multoties breviore; seminibus subglobosis reticulatis. — Base of Santa Catalina Mountains, Arizona; fl. April, *C. G. Pringle.* This is distinguished from all the North American species by its rosulate leaves (4 to 6 or 8 lines long) and almost naked stem, 2 to 6 or 8 inches high, with small and narrow distant leaves, and few (rarely more than 4 to 6) very long-peduncled flowers; these are scarcely more than 5 lines long, rose-purple with yellow throat; anthers (soaked) from half to nearly a full line long; stigmas broadly fan-shaped. From the nearly allied *E. Douglasii* it is distinguished by its radical leaves and whole growth, by a much shorter flower-tube in proportion to the lobes, and rather smaller seeds.

Gentiana microcalyx, Lemmon in litt. Annua, erecta, pedalis seu sesquipedalis, fastigiato-ramosa; foliis sessilibus e basi subcordata ovato-lanceolatis margine sub lente scabrellis; floribus inferioribus longe pedicellatis in apice ramulorum cymoso-aggregatis (fere 5 lin. longis albidis demum pallide violaceis); calyce profunde inæqualiter 5-lobo tubo corollæ ter quaterve breviore; lobis corollæ patentibus lanceolatis acutiusculis basi nudis tubo subcylindrico brevioribus; ovario subsessili in stylum brevissimum attenuato; seminibus globosis læviusculis. — Arizona, *Mr. & Mrs. Lemmon.* — Leaves thin, and, with the exception of the middle ones, almost without nerves, from an inch to an inch and a half long. Flower 5 lines, calyx 1 line long. Allied to *G. Wislizeni* of the same region, but distinguished by the smaller proportions, thinner leaves, and especially the shape of the calyx and the absence of any fringe in the throat of the corolla, whereby it stands next to the much larger and coarser *G. quinqueflora.*

G. Engelmann.

Mr. Lemmon has published a description and a woodcut of this new Gentian in the Pacific Rural Press, of Feb. 25, 1882. It was collected on the summit of the Chirricahua Mountains, in the southern part of Arizona, Sept. 30, 1881.

Gilia (Navarretia) prostrata. *G. leucocephalæ* proxima, sed humifusa capitulo primario radicali, ramisque inferne nudis apice capitulum foliis involucratum gerentibus quasi prolifera; calycis tubo parce hirsuto; ovulis seminibusque in quoque loculo 4. — Near Los Angeles, California, on the margin of desiccated ponds, *Rev. J. C. Nevin*, 1879, 1881, *Dr. Parry*, 1881.*

Phacelia Pringlei. *Euphacelia*, *P. namatoidei* proxima, gracilior, glanduloso-pubescens, aperte ramosa; foliis linearibus basi attenuatis, inferioribus oppositis, omnibus pseudo-racemis gracilibus brevioribus; sepalis linearibus corolla fere rotata cærulea dimidio brevioribus. — Mountains about the head-waters of the Sacramento River, N. California, at 7,500 feet, *Pringle*, 1881. This is interesting as connecting the anomalous *P. namatoides* with the ordinary Phacelias. Only one or two pairs of leaves are opposite; the inflorescence is as free from circination as in that species.

Phacelia platyloba. *Euphacelia* inter species pl. m. glandulosas nec setosas, gracilis, pube brevi molli subviscosa; foliis parvulis pinnato-5-partitis, segmentis oblongis crenato-incisis, terminali majore subpinnatifido; floribus in spica angusta breviter pedicellatis subconfertis; calycis lobis e basi angusta valde dilatatis foliaceis (1 vel 2 subito in laminam oblato-ovatam, cæteris minoribus obovato-spathula-

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* It has at length become evident that the unequal insertion of the stamens (so characteristic of *Phlox*) will no longer serve to distinguish *Collomia* from *Gilia*. Transitions occur in the same species from very unequal to equal insertion, or nearer to equality than in some other Gilias besides those of the Navarretia section. The character of solitary ovules having also failed, nothing remains but to remand Nuttall's genus *Collomia* to the already large and much diversified genus *Gilia*. Fortunately not many new names will be required: For the

C. Cavanillesiana, Don, is *Gilia glomeriflora*, Benth.

C. Cavanillesiana, Gray, as to the United States plant, is *G. multiflora*, Nutt., from which one or two other species or forms are still to be extricated.

C. Thurberi, Gray, has to be *G. Thurberi*.

C. longiflora, Gray, is *G. longiflora*, Don.

C. aggregata, T. C. Porter, is *G. aggregata*, Spreng.

C. leptalea, Gray, is *G. capillaris*, Kellogg.

C. heterophylla, Hook., is *G. Sessei*, Don.

C. gilioides, Benth., with *C. glutinosa*, is *G. divaricata*, Nutt.

C. gracilis, Dougl., is *G. gracilis*, Hook.

C. tenella, Gray, may be named *G. leptotes*.

C. linearis, Nutt., can retain the specific name of *G. linearis*, and

C. grandiflora, Dougl., that of *G. grandiflora*, the homonym of Steudel being *G. densiflora*.

tis); corolla subrotata cærulescente, appendicibus brevibus obtusissimis; capsula in exemplo abortu monosperma oblonga acutiuscula (lineam longa) calycem haud superante; semine subrugoso. — California, in Fresno Co., 1881, *Parry*. The species of this group are not very clearly defined; but no one has a foliaceous calyx of this fashion. The expanded corolla is barely 4 lines in diameter. The fruiting calyx does not exceed 2 lines in length; and the one or two quasi-petiolate lobes are a line in breadth.

Eriodictyon angustifolium, Nutt., var. pubens. Foliis sæpe latiuscule lanceolatis haud lucidis supra puberulis subtus tomentulosis; ramulis pube brevi et calycibus villo denso indutis. — San Bernardino Co., California, 1881, *S. B. & W. F. Parish*, *Parry*. With the foliage of *E. glutinosum* as to shape, and a pubescence which makes some approach to that of *E. tomentosum*, this has the short and nearly campanulate corolla of *E. angustifolium*, to which it is accordingly referred.*

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* *Revision of the Racemose Basi-bracteate Species of* Echinospermum, *in Correction of the Syn. Flora of N. America, ii. p.* 189.

1. Very loosely and small-flowered biennials, or perhaps sometimes annuals: corolla and nutlets not over 2 lines broad or long; leaves thin and green.

E. Virginicum, Lehm. Nutlets of the globose fruit equally short-glochidiate over the whole back.

E. pinetorum, E. L. Greene, in herb. Cauline leaves small, narrowly oblong, mostly obtuse: racemes erect and simple: nutlets only marginally glochidiate with flattened prickles, but the flat or concave ovate dorsal disk glochidiately muriculate. — New Mexico, on the Pinos Altos Mountains, July & Sept. 1880, *E. L. Greene*.

E. deflexum, Lehm. Nutlets only marginally glochidiate, with the dorsal disk minutely scabrous: in var. Americanum (which makes some approach to *E. Virginicum*) the somewhat more granulate dorsal disk not rarely bears two or three small glochidiate prickles on an obscure midnerve!

2. More or less larger- and less loosely-flowered: racemes usually paniculate: tube of the corolla not at all or only slightly surpassing the calyx: glochidiate prickles either wanting on the back of the nutlets or shorter and smaller than those of the margin.

* Biennials: dorsal disk of the nutlets wholly unarmed, granulate-scabrous.

E. ursinum, E. L. Greene, in herb. Hispidulous or hispid on the stem and leaves, stout: nutlets small (2 lines long), with broadly ovate dorsal disk plane or nearly so, the subulate flattened marginal prickles short. — New Mexico, on gravel beds of Bear Cañon in the Bear Mountains, New Mexico, 1880, *E. L. Greene*. To this, in flower only, evidently belongs no. 633, *Fendler*, N. Mexican Coll., which had been referred to the next species.

E. floribundum, Lehm. Pubescent, rather strict: nutlets larger, with

Eritrichium intermedium. *E. Krynitzkia, E. muriculato* affine, admodum varians; nuculis ovato-lanceolatis (ex ovata sursum sensim

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ovate-deltoid dorsal disk more or less carinately one-nerved, margined by a series of long flat subulate prickles. — The syn. "*E. subdecurrens*, Parry, &c ," to be excluded, as it belongs, along with many of the specimens referred here, to the next species. Corolla commonly 3 lines in diameter.

* * Perennials, larger-flowered (corolla usually 5 lines in diameter): dorsal disk of the nutlets sparsely armed with much shorter and smaller glochidiate prickles than the flattened and basally dilated marginal ones.

E. diffusum, Lehm. Pubescent and often canescent with soft hairs or with leaves hispidulous, branched from the base: pedicels usually slender: nutlets with broadly ovate dorsal disk; the ventral face roughish and dull; the marginal prickles as in *E. floribundum*: but mature fruit not seen.— Lehm. Pug. ii. 23; Hook, Fl. Bor.-Am. ii. 83, not Gray, Syn. Fl., in which this species is mixed with *E. floribundum*. *Rochelia patens*, Nutt. Jour. Acad. Philad. vii. 44. *Echinospermum subdecumbens*, Parry in Proc. Davenport Acad. i. 48. Douglas's plant, on which the species was founded by Lehmann, is a low and leafy form, quite cinereous, with altogether immature fruit. When well known it may give characters specifically to distinguish the following:

Var. hispidum. Stem and leaves truly hispid: nutlets broadly ovate (3 lines long), with marginal prickles completely confluent for more than half their length into a wing, the ventral face very smooth and lucid. — Eastern Oregon, on rocky hills and gravelly banks, *Cusick*, 1880 and 1881; and near Boise City, Idaho, *Dr. T. E. Wilcox*, 1881.

* * * Perennial, with simple stems from a multicipital caudex, comparatively large-flowered (limb of the nearly rotate corolla half an inch in diameter), linear-leaved, sericeous: fruit wholly unknown; probably of this genus.

E. ciliatum. *Cynoglossum ciliatum*, Dougl. in herb. Hook.; Lehm. Pug. & Hook. Fl. l. c. 85. — Douglas's station noted in herb. Hook. is "On the gravelly banks of mountain streams near the head-springs of the Columbia; in herb. Benth. Kettle Falls and Spokan River, 1826." The fruit is a great desideratum. *Cynoglossum Howardi*, with which it was rightly associated in the Syn. Flora, p. 188, is evidently only a dwarf and probably alpine variety of the same species, in which the sericeous hirsute pubescence is all still appressed. In the plant of Douglas spreading and more bristly hairs fringe the margins of the leaves with a kind of ciliation, and there are similar spreading or reflexed bristles on the lower part of the stem. This is a foot or so in height.

3. Comparatively large-flowered, perennial, with tube of the corolla surpassing the calyx and about the length of the lobes: nutlets of the globose fruit equably armed over the whole surface and margins with long and slender but flattish minutely glochidiate prickles.

E. Californicum. *E. diffusum*, Gray, Syn. Fl. l. c. (excluding small-flowered specimens which belong to the true *E diffusum*, and excl. syn. Kellogg?) not of Lehm. — Sierra Nevada, California, from Mount Shasta southward. This was ad apicem attenuatis nunc valde papilloso-muricatis; ab *E. barbigero* differt calyce sæpius dimidio minore haud villoso; nuculis sæpius 4 fertilibus. — Southern part of California (from Los Angeles, *Nevin*, &c.) to adjacent Arizona. Not uncommon in collections, has been confounded at times with both of the two species mentioned: if it should pass into *E. muriculatum*, the character of that species would require much extension. It has been collected by *Parry*, *Lemmon*, *Parish*, *Cleveland*, &c.

ERITRICHIUM RACEMOSUM, Watson in herb. *Krynitzkia*, *Pseudo-Myosotis*, e basi lignescente perenne, ramosissimum, setis rigidis subsparsis hispidum; foliis linearibus parvulis; floribus racemoso-paniculatis sparsis, nonnullis folioso-bracteatis; pedicellis flori subæquilongis; calyce setis rectis patentissimis rigidis instructo, segmentis lanceolatis acutis tubo corollæ albæ breviter hypocrateriformis brevioribus; nucula fertili sæpius unica (fere lineam longa) e basi lata sursum angustata dorso parce muriculata intus sulco sursum angustato tota longitudine gynobasi subulata in stylum sat gracilem producta adnato. — Mesquite Cañon, San Bernardino Co., California, March, 1881, *S. B. & W. F. Parish*. The calyx and pedicel appear to be persistent.*

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taken for Lehmann's *E. diffusum*, because of his description of the corolla ("Corolla alba? magna, tubus calyce paullo longior sensim ampliatus"); and Californian specimens of the real *E. diffusum* were mixed with it. The original specimens of the latter do not have the exserted tube of the corolla which marks the present species when in blossom, as does the fruit at maturity. It is the *E. nervosum* of Kellogg; but neither the leaves nor the sepals are perceptibly nervose (the former not "3–5-nerved" nor the latter "3-nerved"), so that the name would be a false one.

*** *E. Mexicanum*, Hemsl. (*Cynoglossum Mexicanum*, Schlecht, in Linnæa, & DC. Prodr. x. 156), is an apparently biennial species with slender prickles covering the whole surface of the fruit, but with corolla-tube not exceeding the calyx.

* ERITRICHIUM, § PLAGIOBOTHRYS.

Good specimens and careful notes, kindly communicated by the Rev. J. C. Nevin of Los Angeles, and a consequent re-examination, enable me to distinguish the species of the first subdivision in the Syn. Fl. N. Amer. (p. 192) more clearly than is done in that work. It will be seen that one of them requires a change of name.

E. FULVUM, A. DC., the *Myositis fulva*, Hook. & Arn. Bot. Beechey, p. 38, and I suppose *Plagiobothrys rufescens*, Fischer & Meyer, as appears from the habitat, were all founded on the Chilian plant. My specimens of this, from Bertero's

Lithospermum (Rhytispermum) glabrum. Humile, e radice annua ramosum, læve, præter pube parca adpressa minuta glaberrimum; foliis spathulato-linearibus; bracteis inflorescentiæ spiciformis densifloræ demum elongatæ nullis; floribus fere sessilibus; calycis segmentis subspathulato-linearibus foliaceis corollæ albæ æquilongis, fructiferis costa inferne valde incrassata indurata; nuculis oblongo-ovatis subtriquetris fere lævibus opacis, areola basilari haud magna. — Apache Pass, S. Arizona, *Lemmon*, 1881. A singular species of Old-World type, somewhat like *L. incrassatum* of Gussone; the base of the calyx and its exceedingly short pedicel similarly thickened and indurated after flowering; but the flowers are not accompanied by bracts, the nutlets are narrower, slightly contracted at base and with less dilated areola of insertion, and quite inclosed in the indurated base of the calyx.

Jacquemontia Pringlei. *J. abutiloidei* affinis, facie *Abutili*, erecto-diffusa e basi frutescente, haud volubilis; foliis cordatis breviter acuteque acuminatis integerrimis utrinque cum ramis canescenti-

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and from C. Gay's collection, although destitute of good fruit, plainly differ from the North American species. The calyx is 5-parted all but to the base into linear lobes. There is no evidence that it connives over the fruit, and it seems that it cannot be circumscissile.

E. nothofulvum, of California and Oregon, the *Myosotis fulva*, Hook. Bot. Beechey, Suppl. p. 369 (that of Hook. Fl. Bor.-Am. is probably *E. tenellum*, Gray), *E. fulvum*, A. DC. as to Calif. plant; Gray, Proc. Am. Acad. x. 57, &c. Erect from a rosulate tuft of thinnish radical leaves; the slender comparatively simple stems reaching a foot or two in height: spikes ebracteate except sometimes at base: calyx 5-cleft barely to the middle into oblong-lanceolate and hardly at all accrescent lobes, closely connivent over the fruit, promptly circumscissile above the base. The pubescence of the calyx, although generally rufous, is often whitish.

E. canescens, Gray, l. c. Diffusely spreading or depressed, or sometimes ascending, more canescently hirsute, but the tips of the calyx at first not rarely rufous: leaves of firmer texture: spikes bracteate below and sometimes throughout: calyx 5-parted (fully two thirds to the base); the lobes broadly triangular-lanceolate or broader, accrescent, open in fruit, tardily when at all circumscissile close to the base.

Var. Arizonicum, Greener, more hirsute or hispid, with somewhat the aspect but not the fruit of *E. Torreyi*: corolla smaller, sometimes with a tinge of rose-color: calyx less accrescent: rugæ of the nutlets rather sharper and towards the sides rising sometimes into elevated points or tubercles. — Arizona, *Greene*, *Pringle* S. Utah, *Marcus Jones*. An intermediate form, collected on the Mesas near San Bernardino by the *Brothers Parish*, has soft-hirsute pubescence, softer leaves, the upper ones forming conspicuous bracts to the loose spikes, and very accrescent mostly wide-open calyx.

tomentosis; pedunculis folio longioribus 2–3-floris; floribus pedicellatis; sepalis acutis vel parum acuminatis, 3 exterioribus ovatis, interioribus subovatis tenuioribus dimidio minoribus; corolla ut videtur alba, limbo pollicem lato. — S. Arizona, in the Santa Catalina Mountains, *Pringle*, May, 1881.

EVOLVULUS LÆTUS. *E. Arizonico* affinis, sed pilis longis patentibus villosus atque indumento sericeo undique argentato-sericeus, multicaulis e basi perenni suffrutescente; caulibus erectis foliosis; foliis lanceolatis sessilibus (majoribus ultra-semipollicaribus, summis lin. 2–3 longis); pedunculis 1–3-floris folia pl. m. superantibus; corolla cærulea semipollicem diametro. — Mesas and foot-hills of the Santa Rita Mountains, S. Arizona, *Pringle*.

BREWERIA MINIMA. Pusilla, e radice annua diffusa, pubescens; foliis lanceolatis basi attenuatis, imis spathulatis; pedunculis unifloris folio brevioribus versus apicem bibracteatis; flore lin. 2–3 longo; corolla violaceo e calyce parum exserta, lobis subovatis; stylo bipartito. — Northern part of Lower California, April, 1882, *Marcus Jones*, *Parry*, *Pringle*. This has the aspect of an *Evolvulus* and of the *Stylisma* section of *Breweria*.*

PENTSTEMON PARISHII. *P. spectabili* et *P. Clevelandi* affinis, pariter glaberrimus, glaucescens; caule 2–3-pedali; foliis integerrimis vel tenuissime denticulatis, caulinis præsertim superioribus oblongo- seu ovato-lanceolatis e basi subcordata semiamplexicauli haud connatis; panicula ampla effusa, pedicellis gracilibus; corolla (pollicari) angusto-infundibuliformi roseo-rubra mox violascente, limbo parvo subæquali, lobis lin. 2 longis; filamento sterili glaberrimo. — S. E. California, in

* It may here be noted that an inspection of the originals in the Sherardian herbarium enables me to eliminate two false species of *Convolvulaceæ* introduced by Pursh, which have given trouble, viz.: —

Convolvulus Sherardi, Pursh, Fl. ii. 730. This is founded on a poor fruiting specimen of *Convolvulus micranthus*, R. & S., which was collected in the West Indies, not in "Carolina."

Calystegia paradoxa, Pursh, l. c. 729. The specimens belong to *Convolvulus hirsutus*, Bieb. (*C. sagittatus*, Sibthorp), and were doubtless collected by Sibthorp in Greece. There are two tickets with the specimen: one with the phrase "Convolvulus hirsutus anguloso folio, fl. albo;" the other, which is there through some misplacement, is the one which Pursh has copied, and which led him wrongly to conclude that the plant came from Virginia.

Calystegia Catesbeiana, Pursh, l. c., is founded on a specimen from Catesby in the same cover as the above (no. 343); I had already rightly referred it to the *Convolvulus sepium*, var. *repens*, but it is one of the forms which may almost as well be referred to *C. spithamæus*.

the Cucamonga Mountains and elsewhere, *Wallace* (panicles only, referred in Syn. Fl. 265, to *P. Clevelandi*), *S. B. & W. F. Parish*. *P. Clevelandi*, of which the best specimens have now been received from the Brothers Parish (who are most zealously and admirably developing the botany of the region) appears to hold to the bearded sterile filament, has decidedly smaller and narrower corolla, of more crimson color; the leaves are rigid, very acutely and rigidly dentate, and the upper pairs almost always connate into an oblong or oval disk. With *P. spectabilis* this equally showy species accords only the character of the panicle and the glabrous filament, the corolla being less ampliate above, &c. I am glad to dedicate the species to the botanists who alone have collected it (except for the imperfect and misunderstood specimens of the late Mr. Wallace) and have enabled me to make it known.

PENTSTEMON BREVILABRIS. Glaber, glaucescens, e basi lignescente ramosus, ultra-spithamæus; foliis coriaceis integerrimis oblongo-lanceolatis imisve spathulatis; thyrso angusto elongato, pedunculis paucifloris brevissimis; calycis segmentis lanceolatis prorsus herbaceis; corolla vix semipollicari (albida?) sursum ventricosa parum bilabiata, lobis subconformibus brevissimis; filamento sterili antheriferis fere conformi nudo. — Cerros Island, Lower California, *S. Belding*, 1881.

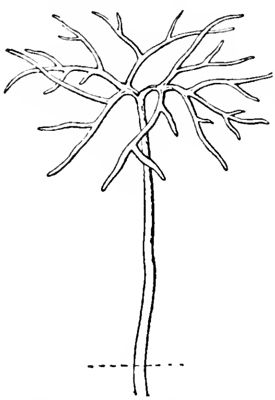
ORTHOCARPUS PARISHII. *Triphysaria* antheris omnibus bilocularibus, ultra-spithamæa, ramosa; foliis 3–5-fidis ramisque fere glabris, lobis lineari-filiformibus; bracteis 5-partitis foliis consimilibus summisve purpureo tinctis cum calyce tenuiter pubentibus flore brevioribus; lobis calycis lanceolatis obtusis tubo dimidio brevioribus; corolla purpurascente labio sæpius pallido, saccis tam latis quam longis, fauce parum pubescente, galea lanceolata obtusiuscula extus puberula. — San Jacinto Mountain, San Diego Co., California, *S. B. & W. F. Parish*, July, 1880.

CORDYLANTHUS (ADENOSTEGIA) NEVINII. Paniculato-ramosus, subvillosus; foliis tripartitis integrisque angusto-linearibus haud calloso-apiculatis; floribus secus ramulos graciles sparsis nudiusculis; corolla flavido-purpurascente; staminibus 4 consimilibus; filamentis villosis; antheris unilocularibus, loculo altero rudimentario vel sæpe nullo; seminibus lævibus scarioso-apiculatis. (To stand next to *C. tenuis*, and the subsection in Syn. Fl. to be widened on account of the essentially one-celled anthers.) — California, in the San Bernardino Mountains, at about 5,000 feet, *Rev. J. C. Nevin*, 1880, *S. B. & W. F. Parish*, 1881.

Monardella tenuiflora, S. Watson in herb. Soror *M. macranthæ*, Gray, fruticuloso-cæspitans, spithamæa, tomentuloso-cinerea; foliis parvis (lamina lin. 3–4 longa) ovalibus ovatisve; capitulis multifloris; bracteis oblongis; corolla albida, tubo filiformi longe exserto (ultra-semipollicari) lobis oblongo-lanceolatis multoties longiore. — S. California, at San Jacinto, in San Diego Co., July, 1880, *S. B. & W. F. Parish.*

Appendix.

Bursera microphylla, Gray, Proc. Am. Acad. v. 155. This shrub was collected by Xantus at Cape San Lucas, Lower California,



in fruit, and soon after by Schott, in Sonora, with a few flowers. It appears to have all the characters of *Bursera*, except that, according to Torrey's notes, the ovules are solitary in the cells. In the original description is the phrase, " Cotyledones contortuplicatissima." Recently Dr. Parry and the Messrs. Parish have collected it in Arizona, near Maricopa, in fruit, and have raised seedlings. When sending some seeds, the Brothers Parish called my attention to the singularly dissected cotyledons. They are here represented from a drawing of a seedling raised in the Botanic Garden of Harvard University, the figure a little larger than life. Bentham and Hooker state that the cotyledons of *Bursera* are " interdum trifidæ." In this species they are biternately dissected into narrow linear lobes. The leaves of the next pair are simpler, the secondary lobes being fewer and short; the succeeding are pinnately parted into seven leaflets, passing toward the adult leaves, which are pinnate with numerous very small leaflets on an interruptedly margined rhachis.

XIII.

THE WEDGE PHOTOMETER.

By Edward C. Pickering.

Presented May 10, 1882.

Much attention has recently been directed to the use of a wedge of shade glass as a means of measuring the light of the stars. While it has been maintained by various writers that this device is not a new one, the credit for its introduction as a practical method of stellar photometry seems clearly to belong to Professor Pritchard, Director of the University Observatory, Oxford. Various theoretical objections have been offered to this photometer, and numerous sources of error suggested. Professor Pritchard has made the best possible reply to these criticisms by measuring a number of stars, and showing that his results agreed very closely with those obtained elsewhere by wholly different methods. His instrument consists of a wedge of shade glass of a neutral tint inserted in the field of view of the telescope, and movable so that a star may be viewed through the thicker or thinner portions at will. The exact position is indicated by means of a scale. The light of different stars is measured by bringing them in turn to the centre of the field, and moving the wedge from the thin towards the thick end until the star disappears. The exact point of disappearance is then read by the scale. The stars must always be kept in the same part of the field, or the readings will not be comparable. By a long wedge the error from this source will be reduced. A second wedge in the reversed position will render the absorption uniform throughout the field. Instead of keeping the star in the same place by means of clockwork, the edges of the wedge may be placed parallel to the path of the star, when the effect of its motion will be insensible. To obtain the best results the work should be made purely differential, that is, frequent measures should be made of stars in the vicinity assumed as standards. Otherwise large errors may be committed, due to the varying sensitiveness of the eye, to the effect of moonlight, twilight, &c., and to various other causes.

A still further simplification of this photometer may be effected by substituting the diurnal motion of the earth for the scale as a measure of the position of the star as regards the wedge. It is only necessary to insert in the field a bar parallel to the edge of the wedge and place it at right angles to the diurnal motion, so that a star in its transit across the field will pass behind the bar and then undergo a continually increasing absorption as it passes towards the thicker portion of the wedge. It will thus grow fainter and fainter, until it finally disappears. It is now only necessary to measure the interval of time from the passage behind the bar until the star ceases to be visible, to determine the light. Moreover all stars, whether bright or faint, will pass through the same phases, appearing in turn of the 10, 11, 12, &c., magnitude, until they finally become invisible. For stars of the same declination, the variation in the times will be proportioned to the variations in the thickness of the glass. But since the logarithm of the light transmitted varies as the thickness of the glass, and the stellar magnitude varies as the logarithm of the light, it follows that the time will vary as the magnitude. For stars of different declinations, the times of traversing a given distance will be proportional to the secant of the declination. If δ, δ' are the declinations of two stars having magnitudes m and m', and t, t' are the times between their transits over the bar and their disappearances, it follows that $m' - m = A\ (t \sec \delta - t' \sec \delta')$. For stars in the same declination calling $A \sec \delta = A'$ we have $m' - m = A'\ (t - t')$. Accordingly the distance of the bar from the edge of the wedge is unimportant, and, as in Professor Pritchard's form of the instrument, it is only necessary to determine the value of a single constant, A. Various methods may be employed to determine this quantity. Professor Pritchard has recommended reducing the aperture of the telescope. This method is open to the objection that the images are enlarged by diffraction when the aperture is diminished; constant errors may thus be introduced. Changing the aperture of a large telescope requires some time, and in the interval the sensibility of the eye may alter. These difficulties are avoided by the following method, which may be employed at any time. Cover the wedge with a diaphragm in which are two rectangular apertures, and place a uniformly illuminated surface behind it. Bring the two rectangles into contact by a double image prism, and measure their relative light by a Nicol. From the interval between the rectangles and the focal length of the telescope the light in magnitudes corresponding to one second, or A, may be deduced. Perhaps the best method with a small telescope is to measure a large number of stars whose light has already been determined photometrically, and deduce A from them.

The great advantage claimed for this form of wedge photometer is the simplicity of its construction, of the method of observing, and of the computations required to reduce the results It may be easily transported and inserted in the field of any telescope like a ring micrometer. The time, if the observer is alone. may be taken by a chronograph or stop-watch. Great accuracy is not needed, since if ten seconds correspond to one magnitude, it will only be necessary to observe the time to single seconds. The best method is to employ an assistant to record and take the time from a chronometer or clock. If the stars are observed in zones, the transits over the bar serve to identify or locate them as well as to determine their light. A wedge inserted in the field of a transit instrument will permit the determination of the light of each star observed without interfering with the other portion of the observation. If the stars are all bright, time may be saved by dispensing with the thin portion of the wedge. In equatorial observations of asteroids the light may be measured photometrically with little additional expenditure of time. Perhaps the most useful application would be in the observation of zones. When the stars are somewhat scattered it would often happen that their light might be measured without any loss of time. By this instrument another field of usefulness is opened for the form of horizontal telescope advocated at a former meeting of this Academy (Proc. Amer. Acad. XVI. 364). Very perfect definition would not be required, since it would affect all the stars equally. To an amateur who would regard the complexity of an instrument as a serious objection to it, a means is now afforded of easily reducing his estimates of magnitude to an absolute system, and thus rendering them of real value.

XIV.

ON THE COLOR AND THE PATTERN OF INSECTS.

By Dr. H. A. Hagen.

Presented April 12, 1882.

"Probably there is scarcely a dash of color on the wing or body of an insect of which the choice would be quite arbitrary, or which might not affect its duration for thousands of years." These words were written by Sir Charles Lyell in a letter to Sir John Herschel in 1836.* This letter, which is a real treasure of thought, asserts clearly that the writer assumes "such contrivances must sometimes be made, and such relations *predetermined* between species," for the protection of their existence.

Though it has been accepted generally that certain colors and patterns of insects might be a protection against enemies, these interesting facts have been mentioned only occasionally, and a general review is still a desideratum. Professor Weismann † has given a very elaborate paper on the origin of the pattern of caterpillars. The paper, as stated in the preface, intends an examination of the pattern strictly for the purpose of finding out whether all patterns can be accepted as the consequences of selection and adaptation, and as produced in a *purely mechanical manner*, or whether some unknown power has to be accepted in part or entirely to explain the pattern. The writer reaches the conclusion that the latter is not the case, and that the known principles of selection and adaptation explain the different patterns. The choice of caterpillars was made purposely to

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* Life, Letters, and Journals of Sir Charles Lyell, Bart., London, 1881, vol. i. p. 469; Nature, No. 633, Dec. 15, 1871, p. 147.

† Dr. A. Weismann, Studien zur Descendenz-Theorie, Leipzig, 1875, vol. i.; 1876, vol. ii. Die Entstehung der Zeichnung bei den Schmetterlings Raupen.

exclude entirely a third factor, sexual selection. Everybody will follow Professor Weismann's careful and elaborate study with interest, though it is probable that the examination of a larger number of exotic species (he has chiefly used European) will change, or at least modify, some of his statements.*

Nevertheless, if it is to be assumed with Professor Weismann that the colors and the pattern originate in a purely mechanical manner, there seems to be a large gap still to be filled. The statement that color and pattern appear in a caterpillar by selection and adaptation as a beneficial protection, without showing how they have been produced, where they come from, which part of the body, and what kind of chemical process brings them out, represents simply a belief. Belief is, as it is well known, beyond discussion, as long as it is based upon views which cannot otherwise be proved. But as the author has prominently advanced that the origin of the color and the pattern is only the consequence of mechanical arrangements, excluding entirely predetermining power, the possibility of such mechanical arrangements should have been proved satisfactorily.

If we compare side by side Sir Charles Lyell's letter with the accepted predetermination and Professor Weismann's work with the denied predetermination, there seems to be no difference except in the belief of both authors.

The conviction that color and pattern are the consequence of existing laws and actions in the body of the insect, induced the present writer to extend his study in that direction. May it not be considered too assuming, if the result shall prove inadequate to the purpose. The first step in all such questions is the most difficult, and often nothing more is left to be said about it, except that it was the attempt of the first step.†

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* Of North American Sphingidæ the previous stages of fifty-four species are known, and of fifteen species all stages. With very few exceptions all were published before 1874. Of the European species all stages were described long ago of eight species: *Sphinx ligustri* by Schwarz; *Sph. pinastri* by Sepp, Ratzeburg, Hartig, Schwarz, Klopsch; *Deil. euphorbiæ* by Sepp, Rösel, Schwarz; *Deil. porcellus* by Sepp; *Smer. tiliæ* by Rösel, Reaumur; *Smer. ocellata* by Sepp; *Smer. populi* by Sepp, Schwarz; *Deil. nerii* by Rossi. With few exceptions excellent figures are given. The literature is therefore not so scanty as has been assumed, though not sufficient for the purposes of the author.

† Some parts of the present paper were published in the Amer. Natural. 1872, pp. 388–393, and Entom. Monthly Mag. 1872, ix. pp. 78–83, Mimicry in the Colors of Insects.

The Color.

As most insects are more or less colored, color is an important character. I have said purposely insects, and not arthropods, because my studies have not extended to the other groups. Some facts, of course, can be applied to all; but the other groups are not to be compared for the frequency and for the intensity of the colors with those of insects. There is no doubt that the different colors of insects are the consequence of the contact of the animal with air and light; or at least that colors are more strongly developed by both these factors. The only contrary statement known to me is by Professor Sachs, and will be considered later. The influence of light is proved by the colorlessness of cave insects, of the larvæ living in the earth or in the interior of plants or animals, even by some insects living only a very short time in the open air, as certain very small Ephemerina and Diptera. It is proved by these facts that colors of organic bodies, plants, and animals are found prominently in their external coverings. Therefore the Greek philosophers considered color to be the product of a chemical action, called by them πέψις, boiling. The interior of organic bodies is mostly colorless or discolored. There exist, indeed, exceptions even in insects, but at least a part of these internal colors is to be found in places which are in contact with the air. The tracheæ in Odonata and others are red; the fat body in Trichois red, in Zerene yellow, in Pentatoma green; the Malpighian vessels in some Orthoptera green; the testicles in some Hemerobina, at least in the previous stages, lemon yellow; the anal glands in Osmylus black; the blood in Chironomus red. In other orders we find some internal organs of Holothuria brick-red, of Echinus yellow. After all, we are justified in considering those cases as exceptions, or even as rare ones.

Besides air and light, there is a third factor influencing the development of color, heat and its counterpart, cold. The heat has a well-known prominence in all chemical processes, and of course also in colors if they are the result of a chemical process. The carbonizing of tissues gives to them a certain color by the change which follows the combination of the tissue with oxygen. Such colors are very common, and of different intensity in insects. The brown or black color of many chrysalids, which are inclosed in a cocoon not permeable to the rays of light, is probably the product of carbonization. The importance of heat and of cold for the production of colors in insects has lately been shown by careful and convincing experiments by Dorfmeister,* Weismann,† W. H. Edwards,‡ and others.

The remarkable influence of a wet or dry atmosphere on the colors will be considered later. The interesting albinism and its counterpart, melanism, have not yet been studied to such an extent as to allow of decided conclusions. Albinism is much rarer among insects than among birds; but it is obvious that a satisfactory explanation of these aberrations would permit conclusions about the nature and origin of the colors.

Besides chemical colors, there exist a very different kind, optical colors, which we will consider first.

Optical Colors.

Optical colors, produced by the interference of light, are by no means rare among insects, but they are solely optical phenomena. Colors by the interference of light are produced in two different ways: either by thin superposed lamellæ, or by many very fine lines or small impressions in very near juxtaposition.

There must be present at least two superposed lamellæ to bring forth colors by interference. There cannot be more than four layers in the wings and scales, which show principally such colors in insects, two external ones belonging to the cuticula, and two internal ones belonging to the hypodermis. The naked wings of Diptera and Neuroptera often show beautiful interference colors.

The scales of Entimus and other Curculionidæ are well known for their brilliancy, and it is interesting to remark that when dry scales are examined with the microscope, many are found partly injured, which give in different places different colors, according to the number of layers which remained. The elytra of some Chrysomelina and other beetles with iridescent colors orobably belong to the same category.

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* G. Dorfmeister, Mittheil. des naturwiss. Ver. f. Steiermark, 1879, pp. 3–8; Ueber den Einfluss der Temperatur bei der Erzeugung der Schmetterlings Varietäten (*Vanessa Atalanta*), and ibid. 1864 (not seen by me); Ueber die Einwirkung verschiedener während der Entwicklungsperiode angewendeter Wärmegrade auf die Färbung und Zeichnung der Schmetterlinge.

† Ueber Saison-Dimorphismus der Schmetterlinge, 1875, vol. i.

‡ Mr. D. W. Edwards' (Coalburgh, West Virginia) papers are published, Canad. Entomol. 1875, vol. vii. p. 228; 1877, vol. ix. pp. 18, 203; vol. xiv. 1882, p. 21; Psyche, 1880, vol. iii. Nos. 69, 70; 1881, vol. iii. No. 83.

Since science is so far advanced, that for every color produced by interference of light the distance of the lamellæ is known by calculation, it would be possible to give the exact figures of the distance for every color observed on insects. The wings of some insects show interference colors only for a certain time (Chrysopa, Agrion), as long as the membranes of the wings are soft and not firmly glued together. Later those wings become simply hyaline. On other insect wings those colors remain during lifetime and persist even after death.

Secondly, interference colors are produced by many very fine lines or striæ in very near juxtaposition. Such colors are easily observed by looking in an oblique direction towards a glass micrometer, even not a very finely divided one. Some forty years ago Mr. Barton, a manufacturer in London, used to make iridescent buttons called iris buttons. There were only thirty to forty impressed striæ on a square line. But each adjacent square line had the striæ in another direction. The fine longitudinal and transversal lines of the Lepidopterous scales seem to serve admirably well to produce the brilliant effect of color-changing butterflies. But there must be something more present, as most of the scales of Lepidoptera are provided with similarly fine lines, and only comparatively few species change colors. I remark purposely that the lines in the color-changing scales are not in nearer juxtaposition. The explanation of the fact given a century ago by Rösel,* stating that both sides of the lines (like small prisms) were differently colored, was due to an optical illusion, explained by the insufficient power of the non-achromatic microscopes at that time. There may be a way of explaining this kind of iridescence not yet used by naturalists; I mean calculation. The late Mr. Nobert, of Greifswald, the unrivalled maker of the well-known test-plates, which contain bands differing by the number of lines, had so far advanced that the last band has lines with less than one 100,000th of an inch distance, where the delicate lines of Diatoms are separated from each other by one 50,000th of an inch. Some twenty years ago there did not exist microscopes strong enough to see those lines, and it was doubted by the French Academy if they were really present. Mr. Nobert, as accomplished in mathematics as in mechanics, proved by calculation based upon the interference colors produced by those lines, the space between them. The result agreed perfectly with his previous asser-

* A. J. Rösel, Monatliche Insecten Belustigung, 1755, vol. iii. p. 256, pl. 44.

tions. Now the most powerful microscopes show the lines, and they have been photographed of every band by Dr. Woodward in Washington. But even now science is not entirely equal to mechanics, as the photographs show by some optical illusion six or more lines than were made by Mr. Nobert. Perhaps in the color-changing butterflies natural colors are combined with optical colors, or perhaps interference colors produced by superposed lamellæ are combined with those produced by fine striæ. It will be necessary to deprive the wings of their natural colors by bleaching, and then to make a microscopical examination. I have begun experiments for this purpose. The wings of *Apatura clytie*, a variety of *A. ilia*, are pale yellow in the color-changing part; the wings of *Euploea superba* are velvety black above, the black changing into violet in the color-changing part. Both wings, put in eau de Javelle, began to grow pale after one hour. The paleness began first in the color-changing part of *E. superba*, and was less visible in the much lighter-colored wings of *A. clytie*. After one hour and a half the whole color-changing part of both species was entirely hyaline. The not color-changing parts were very little affected, and in *A. clytie* the light-brown spots were nearly intact. Both wings had lost entirely the change of colors. The microscopical examination showed that the scales of the color-changing parts were very much affected. The scales were hyaline, nearly invisible; the longitudinal striæ less sharp, the transversal ones even more affected, and mostly obliterated. In some places in the middle of the color-changing part the scales had disappeared, and only their stems were left. On the other hand the scales of the not color-changing parts were nearly unchanged, and both kinds of the striæ as sharp as before. The under side of the wings does not change color at all, nevertheless the parts corresponding to those iridescent ones of the upper side were affected as much and in the same manner as the scales of the upper side. From the beginning of the bleaching process both sides made the same progress in becoming hyaline. Now the striæ of the scales, though they had been much affected by the bleaching, could not be the producers, at least not alone, of iridescence, as in all not color-changing scales the striæ are exactly of the same arrangement and distance, just as fine and approximate as in the iridescent ones. Therefore it may be presumed that the lamellæ of the iridescent scales are more distant one from the other, less firmly glued together, and therefore easier affected by the bleaching fluid and the colored substance between the lamellæ easier bleached. But why are the corresponding not iridescent scales of the under side of the wing also affected, and at the same time with those of the upper side? It can only be supposed that the quick effect upon the scales on one side of the wing gives easier access to the scales on the other side. I confess that I am not entirely satisfied with this explanation, but I do not know of a more satisfactory one. For the first experiment the wings were cut through the middle of the color-changing part, and were therefore perhaps more quickly affected. In subsequent experiments with entire wings of *Euploea superba* the iridescence was gone in three-quarters of an hour, but the wing was only less dark even in the color-changing part. In the same space of time wings of *Apatura Iris* and *Ilia*, and of *Thecla quercus* were entirely bleached, those of *Lycæna Damon* only partly. The question whether the striæ of scales with more distant lamellæ will help to produce iridescence, which the same kind of striæ of scales with not distant lamellæ does not do, I am unable to answer.

The colors of butterflies change mostly from purple to blue, sometimes to yellow. Probably a calculation based upon the appearance of these colors might help to solve the question.

An interesting observation by Professor Graber * is here to be noticed. When caterpillars of Apatura are kept in diffused light, the wings of the butterfly show almost no iridescence. The wings of *Vanessa polychloros* have slate-colored marginal spots instead of the commonly blue ones, when the caterpillars are raised under yellow glass. As no authority is quoted, these observations may have been made by Professor Graber himself. It is obvious that here a new and interesting field for experiments is open. The record of Professor Graber's observations is too fragmentary to go farther with conclusions based upon them, the more so as such isolated experiments need always the support of reiterated observations before they can be accepted as facts. This would be needed here even more, as it is difficult to understand how a different light could work through the skin of a caterpillar on the wing of the imago which is scarcely beginning to be built up in the interior of the caterpillar. If true, it would be an important discovery. An observation by G. Schoch † does not corroborate Professor Graber's statement, at least for the

* V. Graber, Insecten, 1877, vol. ii. p. 38.

† G. Schoch. Mittheil. d. Schweizer entom. Gesell. 1880, vol. v. p. 540. Zucht von *Euprepia caja* im gefärbtem Licht.

changing of colors. *Euprepia caja* was raised by him in different colored light. The caterpillars were kept in three boxes, covered with red, violet, and blue glass. Those under violet glass were more voracious than the others, and consumed twice as much food. Their crysalis transformed in the imago a fortnight earlier than the others. But the imagos of all did not show any perceptible difference. Perhaps raising of the caterpillars in diffused or homogeneous light may have a different effect, at least for iridescent butterflies. The Newton color rings viewed with homogeneous (yellow) light change the color of the rings, the dimensions of which grow smaller and smaller between the red and violet rings, in a proportion from fourteen to nine. I do not know that iridescent butterflies have been examined under homogeneous light; perhaps such experiments would allow further conclusions.

Krukenberg * presumes the golden-green color of *Carabus auratus* to be an interference color. It is not changed by the influence of light, nor was he able to extract from the elytra any green pigment with ether, benzol, carbon of sulphur, chloroform, alcohol, even after having submitted the elytra before to the influence of muriatic acid or ammonia. Chlorophyll is not present, whether free or combined with an acid. The chlorophyll found by K. B. Hofmann (Lehrbuch der Zoochemie, 1875, No. 3, p. 368) in the elytra of Cantharis is not present in them, but is derived from the contents of the alimentary canal. The change of the color in Cantharis is probably the consequence of an alteration of the chitinous external integuments by cold weather or by a more elevated habitation.

Interference colors are also produced by very small impressions in juxtaposition. Such an arrangement is found on the feathers of birds; for instance, on the necks of pigeons and elsewhere. In the hairs of Aphrodite and Eunice this arrangement may be compared with striæ (Leydig). Perhaps this kind of interference colors is found more frequently among insects than is commonly known. At least there are often parts of insects, and their limbs in appearance yellowish, but in a certain direction changing to brown or blackish. I know of no other explanation of this not uncommon fact on the legs of Diptera, of Hymenoptera, and of Phryganidæ. G. Pouchet (Des Changements de Coloration sous l'Influence des Nerfs, Journ. de l'Anat. et Physiol.,

* C. Fr. W. Krukenberg: Vergl. physiolog. Studien an den Küsten d. Adria, 1880, 1881, vol. iii. p. 62.

Paris, 1876) has drawn attention to the so-called Iridocystes (Interferenzellen of Brücke). They do not belong to the pigment, but to optical colors, to fluorescence. A large number of small superposed lamellæ become luminous by contraction. They are very brilliant in Saphirina and in a large number of fishes, allowing them to change color according to the color of the bottom on which the fishes are standing. They may occur in some insect larvæ, but have not yet been recorded. I believe that the arrangement in some insects' eyes (Mantis), to be mentioned later, belongs to the Iridocystes. It should be remembered that interference colors, one or both kinds, may occur in the same place together with natural colors. The mirror spots of *Saturnia Pernyi* show besides the interference colors a white substance in the cells of the matrix, which Leydig believes to be Guanin. But this fact is denied by Krukenberg for the same species, and also for *Attacus mylitta* and *Plusia chrysitis* (vol. v. 1881, p. 65).

Natural Colors.

There exist two different kinds of natural colors.

1. The pigment is deposited in the form of very small nuclei in the cells, or in the product of cells, in the cuticula.

2. The pigment is a homogeneous fatty substance, a kind of dye somewhat condensed.

Pouchet speaks of a third kind of natural colors, which are said to be inherent to certain tissues. He mentions them only for the muscles, as I believe erroneously. So I have dropped entirely this kind of colors till a more sufficient proof for their existence is given.

The first kind of natural colors is to be compared with pigment inclosed in air-tight glass tubes; the second is related to a diffusive or fluid pigment.

The first kind of colors belongs to the cuticula, and I will call them *dermal* colors. I consider them to be produced mostly by oxidation or carbonization, in consequence of a chemical process originating and accompanying the development and the transformation of insects. To a certain extent the dermal colors may have been derived from hypodermal colors, as the cuticula is secreted by the hypodermis, and the colors may have been changed by oxidation and air-tight seclusion. The cuticula is in certain cases entirely colorless, — so in the green caterpillar of *Sphinx ocellata;* but the intensely red and black spots of the caterpillar of *Papilio machaon* belong to the cuticula, and only the main yellow color of the body to the hypodermis (Leydig, Histiol., p. 114). A particular main color of the cuticula is assumed by Graber (p. 17), which is said to change the underlying hypodermal colors. As far as my studies go, the color of the cuticula is often somewhat yellowish with a brownish shade, and only the most superficial layers contain pigments, which therefore must have been produced during or directly after the casting of the skin. The layers below the superficial ones were of indifferent color and had nothing to do with the main color of the insect (thorax of *Phanæus carnifex*). Whether this is generally true will be proved by farther observations.

The second kind of colors belongs to the hypodermis, and are called *hypodermal* colors. I consider them to be the consequence of a chemical process, generating color out of substances contained in the body of the insect. These colors may be changed into other colors by light and heat, perhaps by acids or by the influences of the sexual organs. If such a change were to a certain extent a photographic process, some important facts (mimicry) could be understood, which otherwise are inexplicable.

The dermal colors are red, brown, black, and all intermediate shades, and all metallic colors, blue, green, bronze, copper, silver, and gold. The dermal colors are easily to be recognized as such, because they are persistent, never becoming obliterated or changed after death. Dermal colors are not unfrequently retained by insects inclosed in copal, but never by fossil insects inclosed in amber. The persistence of dermal colors is easily understood, as they are formed before the chitine becomes rigid, and later are preserved in a similar manner as if they were inclosed in hermetically-sealed glass tubes.

The hypodermal colors, placed in the soft and not chitinized hypodermis, are easily recognized, because they fade, change, and disappear after death. A fresh or living insect, when opened, can easily be deprived of the hypodermal colors, simply by the action of a small brush. An important exception is to be made in certain cases, in which hypodermal colors are persistent after death as well as dermal colors. In such cases the colors are better protected and inclosed nearly air-tight. I refer to certain colors of the elytra and wings, of the hairs, scales, and appendages of the body. The elytra and wings are, as is well known, at first open bags in direct communication with the interior of the body. The hairs and scales are at first similar open bags, glued together only at a later period. In all of them the hypodermal colors are formed, of course, before the membranes are glued together; after that time those hypodermal colors are nearly as well preserved as dermal colors, except that they are subject to fading after a lapse of time. The possibility of such an inclusion is proved as a fact by the inclusion of air in the white scales of Lepidoptera. The white mother-of-pearl spots of the species of Argynnis are produced by a system of fine transversal pore-canals filled with air; by Hydrometra the white ventral marks have the same origin (Leydig).

The hypodermal colors are mostly brighter and lighter than the dermal ones, — light blue or green in different shades, yellow to orange, and the numerous shades of those colors combined with white. Exceptionally they are metallic, as in Cassida, and are then obliterated after death. The fact which I find quoted, that such metallic colors can be retained in dead specimens by putting a drop of glycerine under the elytra, allows us to conclude that those colors are based upon fat substances. The hypodermal colors are never glossy, as far as I know; the dermal colors frequently.

It must not be overlooked that elytra, wings, and hairs all possess a cuticula, and that even here dermal colors are frequently to be found, together with hypodermal ones, chiefly in metallic colors. In the same place both colors may be present, or one of them alone. So we find hypodermal colors in the elytra of Lampyridæ. In the elytra of the Cicindelidæ the main metallic color is dermal, the white lines or spots are hypodermal; by which arrangement the variability in size and shape of those spots is explained. A large number of Lepidoptera have hypodermal colors in the scales of the wings, — a fact shown by the rapid fading of those species.

There occur in a number of insects external colors, that is, colors upon the cuticula, which I consider to be in fact displaced hypodermal colors, — the mealy pale blue or white upon the abdomen of some Odonata, the white on many Hemiptera, the pale gray on the elytra and on the thorax of the Goliath beetle, and the yellowish powder on Lixus. Some of those colors dissolve easily by ether or melt in heat, and some of them are a kind of wax. I believe that those colors are produced in the hypodermis, and are exuded through the pore canals. Therefore they may be considered as belonging to the hypodermal colors. *Eriosoma alni* is commonly covered with white waxy secretions. When taken off gently a new secretion soon begins to appear out of the pores of the four circular glands which are found on each segment of the abdomen. If the dorsal half of the abdomen of a female is cut off, the fluid contained in the body by its contact with the air changes directly to a white shade, which seems to be of the same nature as the external secretion. Therefore this white secretion would not be strictly derived from the hypodermis, except that it is secreted by hypodermal glands. I am not sure whether some of the colors before mentioned may not be in some way different from the others. In the case of Lixus I find it stated that the mealy powder, when taken off, is renewed in a few days. I confess that my opinion concerning those external colors is not yet entirely settled. That those colors are simply an exudation of fluid in the body through the pore canals is not to be accepted; they must have been changed in passing through the hypodermis. In such Lepidoptera as become oily after death, the fat exudes through the pore canals, and, passing through the hypodermis, reaches the outside of the body unchanged. A chemical investigation would be very desirable, and would perhaps give some better explanation; but the quantity which may be had of those colors is always too small for such a purpose. The blue mealy matter of the abdomen of Odonata when scratched off and brought in contact with ether on a glass slide is directly dissolved, leaving scarcely a margin around the spot after the evaporation of the ether. When the same matter on a glass slide is held over a candle, it melts directly, and after drying a dull whitish spot is left.

Bezold's Views upon the Nature of Colors.

Recent investigations about the nature of colors advance also our knowledge of the colors of insects. The Theory of Color in its Relation to Art Industry, by W. von Bezold,* contains some excellent statements, which allow us to understand better the colors of insects.

1. "*Transparent colors*, so called by artists, are similar in their action to colored glass or to clear-colored solutions. When the light falls upon a shining surface of such colors, a reflection primarily takes place at the upper surface, extending only to a fraction of the impinging light; the remainder enters the colored mass, and there undergoes a process of absorption, so that it is already decidedly colored when it arrives at the ground-surface of the layer. If at this second surface the light strikes upon a white body which reflects irregularly,

* Dr. W. von Bezold: The Theory of Color in its Relation to Art and Industry. Translated by S. R. Köhler. Boston, 1876, &c.

colored rays will be emitted from this layer in all directions which face toward the impinging ray of light, and in the repeated penetration of the colored layer their color will increase in intensity."

I am not yet prepared to assert with certainty that such transparent colors exist in insects. It is obvious that the different layers of the cuticula, when possessing a peculiar color, would answer exactly the conditions above stated, the more so as a glossy surface is frequent among insects. Perhaps some remarks by Graber (Insecten, i. p. 17) belong here. "Most frequently the hypodermis is colored brown or red, even in such insects as are externally entirely green, as the grasshopper, or black, as the cricket. This fact is to be explained partly by the refraction of the cuticula, and partly by its peculiar color." If Graber's observation proves to be true, the explanation will be sufficient, and then we have a right to assume that similar cases may occur among insects. Transparent colors would belong to the dermal colors, modified perhaps by the underlying hypodermal colors.

2. "*Body colors* in an artistic sense [Bezold, p. 57] differ entirely in their action from transparent colors. They are likewise transparent in very thin layers, and with them it is also the light that has passed through the pigment which exhibits the characteristic color of the latter; but the great difference in the optical action of the pigment and of the medium, makes it impossible for the light to penetrate through layers of any perceptible thickness. On account of this difference a division in transmitted and reflected light takes place at all the surfaces of separation of the particles of the coloring matter, so that the portion of transmitted light is already reduced to an almost inappreciable quantity at an insignificant depth below the surface. The same is of course true of the light sent forth by the lower surface, and this explains why such colors are opaque when applied in tolerably thick layers. The light reflected by body colors will always contain a larger quantity of white light than light that is reflected by transparent colors. This is the reason why that brilliancy and depth or fulness can never be attained by body colors as by transparent ones."

It is therefore obvious that just this kind of color is very frequent among insects, and not only in dermal, but also in hypodermal colors, when the cuticula covering them is perfectly hyaline.

3. "*Surface colors* [Bezold, p. 61] are the consequence of bodies which cause a division of the light falling upon them, which allow rays of a specific degree of refrangibility, or, in other words, of certain

colors to enter, while they reflect all others. Such bodies show one color when the light falls upon them, and another when the light is transmitted through them. The metals in very thin leaves are especially prominent in this class of bodies. The various aniline pigments also show such surface colors when dry. Thin layers of those pigments will have a perfectly metallic appearance. Fuchsine or Magenta has a green golden color when the light falls upon it, a purple color when the light is transmitted through it."

The surface colors are prominently interesting for entomology, as they explain for the first time the frequent metallic colors on insects, which have often so true a metallic appearance, that indeed it has been tried to extract the gold out of them. The condition that such layers must be perfectly dry, makes it evident, as I have before stated, that metallic colors must belong to the dermal ones. As I have stated later, that insect colors might with propriety be compared with aniline colors, the whole comparison is even more to the point.

4. "*Fluorescent colors* [Bezold, p. 621] act quite differently from the before-mentioned ones. In all those cases a division of the impinging rays took place, so that a part of the rays entered the body or passed through it, and that the remainder was absorbed or reflected. But the fluorescent bodies transform the light falling upon them into light of another color, that is to say of different wave-length. This is frequently observed in the yellowish-green uranium glass, in fluorspar, in solution of quinine, in petroleum and other bodies. Investigations with the aid of the spectrum show that in the case of bodies of this kind light of the most varied colors is transformed into light of some other definite color, and that even invisible rays can be changed into visible ones, as the ultra-violet rays. The retina possesses in a slight degree the property of fluorescence." I presume that a number of insect colors may probably belong to this kind, namely, the violet shades observed in Rutela and similar beetles.

I have purposely dwelt at length on these phenomena, as I believe that they will throw considerable light upon occurrences till now unexplained.

Hypodermal and Dermal Colors.

The hypodermal colors are very often different in males and females of the same species. The dermal colors rarely differ, so far as I know, in the sexes. But there are some genera with prominent dermal colors, which are nearly always different in both sexes, as Calopteryx, some Hymenoptera, some Coleoptera, and others.

It would be interesting to know exactly the rule for the change of color in males and females. So far as I know, this change seems to be between related colors, and not between complementary ones. But my observations are far from having any conclusive importance; in some cases, as in Hetærina, the change is effected by complementary colors, red and green. The same investigation will have to be made for hypodermal colors. As far as I know, even here the change seems commonly and chiefly between related colors; though some cases of complementary colors have been observed.

The dermal colors never change during lifetime; the hypodermal ones may be changed in some way, and are known to be altered in some instances in a male or female during its lifetime, by sexual or other influences. By sexual influences, for instance, yellow is changed into orange, brown into red (in some Agrion females), milk-white into blue in males, and into green in females (Platyenemis). By other influences, for instance, by cold (Brauer) in hibernation, pale yellow is changed partially into red (Chrysopa). But this change is said to be produced by chromatophores by other naturalists (Leydig). The hypodermal colors in one insect (*Cassida aurichalcea*) are stated to be changed by a voluntary act of the insect, and the new color can again disappear (Harris).

Sexual Selection.

Everybody has studied with interest in Mr. Darwin's works (Descent of Man, vol. i. p. 374; Nature, vol. xxi. p. 237, No. 532) the exposition of his theory of sexual selection. The part concerning the butterflies is a rather prominent one. But when we weigh the given facts, they do not seem to be so conclusive as they are considered to be. Comparatively *very few species* agree very well, or only well, with Mr. Darwin's assertions. The fact that it is only peculiar to butterflies, and does not occur in other families of Lepidoptera, becomes more important when we find that the theory is exemplified only in less than one per cent of the butterflies themselves. Why is the whole main army so much behind? — is a question nowhere found answered. After all, the statement, that the male is so much more beautifully colored for sexual selection, will apply only to exceptional cases among Lepidoptera.

Papilio turnus in North America offers a rather puzzling case. Its southern dark-colored female, formerly *Papilio glaucus*, will be as good an example as any other for an indifferently colored female of a beautifully colored male.

But unfortunately it happens that all the females of *Papilio turnus* in the northern half of North America are so presumptuous as to show the same gay colors as the male, and even brighter and more variegated ones. Both sexes have as caterpillars the same food in the South and in the North. The chrysalis of the dark and gay-colored females is not different, except that I find in two of the dark ones raised by J. Boll in Texas (there occur both forms) a longitudinal blackish ventral band which is not to be seen in the chrysalis of the gay-colored females. There is, therefore, no reason left to understand why this species should form such a strong exception. If the males need something besides beauty in their competition for the females, it seems as if the strongest would always be the winner. But is it sure that the most prominent external beauty always coincides with the most prominent sexual power? I confess that I have some doubt about the fact, as the artificial loss of this power by castration is followed in birds, in mammals, and in an isolated instance in fishes, by an unusual development of external beauty.

The Change of Color.

The color of insects, or at least its changes, may be originated by the influence of the air and its humidity, of the temperature, of the season in which they appear, of the character of the country.

The facts to elucidate such important and interesting changes are still scarce and isolated. The curious season dimorphism belongs here. The facts stated in the publications of Weismann and W. H. Edwards are known to every student, and need not be repeated here.

The darkening influence of a climate or country with a large amount of average humidity, which is so well proved for vertebrates by Mr. J. A. Allen, has a similar effect on insects. The peculiar coloration of animals living in deserts is well known, and to a certain degree repeated among insects. The brilliancy of colors in the tropics has become long ago a commonplace remark. Surely there are to be found in the tropics the most brilliantly and intensely colored animals, but it must not be forgotten that by far the largest number of insects in the tropics are just as indifferently and as darkly colored as those in colder regions.

It is a remarkable fact that cold or arctic regions, where snow and ice prevail, do not form, concerning the color of insects, a counterpart to the tropics to the extent we might expect. Of course we find there white or pale-colored species, but they are by no means numerous, and the so-called winter insects, which are found on the snow, are mostly dark brown or black. But even in the coldest regions beautiful and gayly colored species occur, but mostly yellow, orange, or red ones.

An interesting and only recently studied fact, is the change of colors of the same insect in different countries. Some valuable hints are given by Dr. Speyer (Stettin. entom. Zeit. 1875, p. 103). If the predominant colors of Noctuidæ are gray, brown, or reddish brown, or rather a mixture of black, white, and red, less red and more black has been observed in North American specimens, and less black and more red in European ones of the same species. If the colors are a mixture of yellow and red, just the opposite change is seen; in the North American specimens the red is predominant, in the European ones the yellow.

A few words more about beautifully colored caterpillars. As sexual selection could not have acted here, and as it was observed that some of them were not taken by certain species of birds and lizards, but purposely avoided by them, it was supposed that the splendid color serves here as protection. But if we remember that some birds prefer certain caterpillars, and other birds others, as, for instance, the hairy caterpillars, whose hairy cover suggests the idea of protection, we shall arrive at the conclusion that more observations are needed to confirm the above-quoted supposition.

Water insects are nearly all of the same dark hue, yellowish brown to black, often with an olive shade. Only parts of the body which are uncovered in the air (abdomen of Nepa) are sometimes of a brighter purple color. But even among water insects some are to be found (Hydrachna) of an intense red color.

The climax of the development of the pure and elementary colors seems to be reached in the class of insects. All these colors appear here without any transition whatsoever, even in close juxtaposition.

The Pattern.

The pattern of the colors of insects is a subject very important for every naturalist who studies or describes insects. Till to-day only very little has been published about the pattern. Something is stated by monographers about certain groups or families, but that is all. I believe that a more detailed study of pattern and of the different patterns which are to be found in different groups, and perhaps the development of the law according to which the pattern is changed in different groups, would advance us nearer to the knowledge of its nature and origin. What I know about it is only the first step in this direction.

The pattern is not the product of an *accidental circumstance*, but apparently the consequence of certain events or actions in the interior of the insect, mostly at the time of its development. The proof is easily afforded by the regularity of the pattern in the same genus or in the same family. If studied carefully and comparatively, the pattern of such a genus is the same for all species, but for some of them more or less elaborated. The number of such genera, and even of such families having the same pattern, is so large, that some will be readily remembered by every naturalist. In some families a peculiar and constant pattern can be observed for the head, a different one for the thorax and its limbs, and again another one for the segments of the abdomen. The latter is on the different segments (Hymenoptera, Diptera, Neuroptera, Pseudoneuroptera) mostly the same, but more or less elaborated, and less finished in the first and last segments. To a certain extent the same can be said about the segments of the thorax.

Weismann has studied carefully the origin of the pattern of caterpillars of the Sphingidæ. The caterpillars were chosen by him because sexual selection is thus excluded. When just hatched they are mostly colorless, but after a few hours they almost always become uniformly green.* The pattern appears generally after the first moult in the form of longitudinal bands or lines. There is a dorsal line, and one on each side a subdorsal one, and lower down one along the stigmata. In Chærocampa the subdorsal line is changed on two segments of the thorax into large eye-spots, and disappears entirely on all the following segments. In Deilephila the same line forms a ring-spot on the last segment, which in some species is repeated in former segments. In Smerinthus oblique lines cross the subdorsal line on each segment, and these oblique lines receive colored borders in Sphinx and Acherontia. The caterpillars of Chærocampa and Deilephila change later the green color to a darker one.

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* The young larva of *Deilephila euphorbiæ* is entirely black on leaving the egg (Schwarz), or pale and becoming black after half an hour (Weismann).

Weismann contends that all those patterns and colors possess only a biological value. The green color, which first appears, corresponds to that of the leaves. But in a large caterpillar one main color would be too apparent; therefore longitudinal lines separate the main color into several fields and diminish the danger, the more so when the caterpillar lives among grasses. The oblique lines afford a similar protection, and are even more effectual when the lines have colored borders, which make them resemble the ribs of leaves. The eye-spots of Chærocampa are said to frighten enemies, and the variegated colors of Deilephila to designate them as not eatable. The dark color of full-grown caterpillars of Chærocampa is said to be owing to the impossibility of being protected by any color, on account of its large size. These caterpillars acquire, therefore, the habit of feeding at night, and hide themselves during daytime under dead leaves. As, therefore, every one of the quoted characters is of biological value, they can be explained by means of natural selection, and the necessity to admit a phyletic, or inborn power (immediate, designing, or ordaining power, Crooke) does not exist. The possibility of the existence of such a power is rejected by Weismann.

The conclusions and statements of Weismann are based upon a number of European species. But it seems that the study of exotic species will show that some of these conclusions cannot stand, or will lose at least a large part of their value. The colorlessness of the newly hatched caterpillars is perhaps not without exception in some tropical species. The succeeding green color belongs to the hypodermal colors, but all the longitudinal and oblique lines and the spots belong to the dermal colors. The dorsal line is the consequence of the situation of the dorsal vessel; probably the subdorsal line and the oblique lines are muscular lines, and the stigma line a consequence of the large longitudinal tracheæ.

The large eye-spots on the thoracical segments indicate the place under which the wings are beginning to be formed. Similar spots, but less strongly developed, are to be found in a number of larvæ of Myrmelionidæ. The formation of the wings necessitates a largely accelerated circulation in those places, and therefore an oxidation of the cuticula. These eye-spots belong to the dermal colors. The very remarkable eye-spot in *Pterogon* (*Thyreus*) *Abbottii* appears in the third stage exactly on the same place where before the tailed appendage existed. The change in this species is very interesting. The second stage has as main color a very light grayish pink, and possesses an orange tubercle, surrounded with black, where the first stage had a tailed appendage. The third stage is either similar to *Pterogon œnotheræ*, dark gray with numerous irregular and very fine paler lines and some darker longitudinal ones, or is black, with large transversal bright yellow bands (indeed so large that the color can also be described as yellow with transversal and longitudinal black bands), and both have instead of a tailed appendage a prominently black and large eye-spot. The differently colored caterpillars represent not the two sexes, as I have raised males which are entirely alike in color and pattern, from both forms of the caterpillar. Both forms live on the same vine (*Ampelopsis quinquefolia*), but the yellow ones are rare. All stages live and feed during the daytime on the vine, the very visible pink ones and the yellow ones, which would need some protection, and the gray ones, which do not need it. I remark purposely that the latter does not go in the daytime on dry stems, as Weismann (p. 80) records for *Pterogon œnotheræ*, but feeds on the green leaves together with the other ones.

The question why this pattern, when considered to be the consequence of the before-quoted causes, is not developed in every caterpillar, is still to be answered. A large number of conclusions of a similar character accepted now-a-days are based on exceptions, if we consider the large number of species which do not agree with them. So feed in North America the very large caterpillars of Chærocampa openly, during daytime, contrary to Weismann's statement for the European species. Exactly in the same manner feed openly in daytime a number of uniform light green caterpillars, which must nevertheless be well protected, as they belong to common species. That the variegated colored ones are repugnant to a higher degree than the not variegated ones, is still to be proved. Both are rarely taken here by birds, as far as I know. That such caterpillars live upon poisonous plants is true for some European species (Slater, Trans. Entom. Soc. London, 1877, p. 205). I believe Weismann's statements are only to be admitted as true ones as far as they go, but not in a general way.

I may state that at least one case is known to me where a difference in feeding caterpillars exaggerated the pattern. An entomologist in Prussia a few years ago divided a large lot of Sphinx caterpillars of the same species, and fed both with the same leaves. The stalks of one lot had been placed in fresh water, and of the other lot in salt water. Both grew very well, but the latter differed considerably in color. Nevertheless the imagos were all alike. The caterpillar of *Hemileuca Maia* feeds in Michigan, New York, and Massachusetts on shrub oak (*Q. ilicifolia*), in Maine and in Nevada (?) on *Spiræa salicifolia*. The caterpillars are very little different, but the imago differs considerably. The first ones are largely black, with more or less narrow white bands; the last ones are largely white only with blackish borders, and sometimes the hairs on both sides of the front part of the thorax are also snow white.

Rev. H. H. Higgins (Quart. Journ. of Science, 1868, vol. v. pp. 323–329, pl. 1) gives some remarks on the proximate origin (the appliances immediately engaged in producing the color pattern) and general configuration of the patches, bands, and spots of color on the wings of Rhopalocera. "In the chrysalis state the patterns of the closely folded wings, the like spots on the right and left wings do not coincide; that which becomes a beautifully formed band, begins as a mere line or a shapeless spot. The simplest type of color presents itself in the plain uniform tint when the scales are all colored alike, which is comparatively rare. At first the scales growing on the membrane upon or near the veins show a freer development of pigmentary matter, and in this manner would arise a kind of primary or fundamental pattern, namely, a pale ground with darker linear markings, following the course of the veins (*Pieris cratægi*). This pattern occurs in most of the families. Let it be supposed that at a given distance from the base a portion of the dark scales begins to diverge on each side from the veins. The dark lines thus formed will meet in the middle of the areas between the veins producing a band of scallops having their concavity towards the base of the wing. A similar band nearer to the base would have its convexities in the same direction. If the latter mode of divergence be quickly followed by the former, a row of annular markings between the veins is the result, the simplest form of annular or ocellate spots. In the pupa state the scheme of the future pattern is fully organized, so that by the extension of the soft wings the pattern of the imago is easily performed. From the vein scales arise all the darker markings, enclosing sometimes the areas of pale, ground tint. The modifications of those areas are performed by a blush, the deepening or the intensifying of the color in certain parts of the wing (*G. Cleopatra*). Besides this comes the gloss by iridescence."

Charles Darwin (Descent of Man, vol. ii. pp. 126–127. fig. 52) speaks of the formation and variability of the ocelli on the wings of many Lepidoptera: "Although we do not know the steps by which these wonderfully beautiful and complex ornaments have been developed the process, at least with insects, has probably been a simple one; for, as Mr. Trimen writes to me, no characters of mere marking or coloration are so unstable in the Lepidoptera as the ocelli, both in number and size."

As far as I know there is nothing more published on this subject. In some few instances I have been able to observe how the pattern is produced. In dragon-flies (Odonata) the thorax is transparent and entirely colorless at the moment of transformation. At this time the muscles are in process of formation. The thoracic muscles of the Odonata are, as is well known, very powerful, and rather exceptional in the shape of their tendons. I observed very strong currents of the blood just along the place where the muscles were developing. The rush of the blood was very much accelerated. Now just outside of these we find in Odonata dark lines or bands, which appear to be the result of the formation of the muscles. *Ubi irritatio, ibi affluxus;* therefore it is not improper to conclude that a powerful action in the development of the muscles is here the cause of a stronger combustion and of an oxidation in the adjacent parts of the external crust of insects. But not the pattern of the thorax alone follows the lines of the muscles. On the head we find a certain pattern corresponding to the muscles of the mandibular apparatus; another one on the segments of the abdomen corresponding to the so-called respiratory or abdominal muscles, and another one on the legs corresponding to their muscles. It is important to remember that those patterns are better and more definitely developed in the most powerful flying Odonata, as in the Æschnina, and especially in the Gomphina. The main color of the Gomphina is yellow of different shades, mostly greenish-yellow, and the stronger the species the larger is mostly the pattern of blackish bands.

I have observed the same proceedings in Cicada just emerging from the nympha skin. On the head, thorax, abdomen, and legs appear similar patterns, corresponding to the muscles or to their insertion places. In fact where a stronger circulation exists in insects, the parts become more strongly chitinized and darker colored.

Should my explanation of these facts be accepted, we shall have taken a step forward in understanding the origin of the pattern. I know very well that among the Odonata patterns exist which do not agree with my explanation, and in one case are even opposed to it.

But though most of the patterns can be explained in this manner, there may exist other factors still unknown explaining the opposite patterns. The explanation given can be considered as admissible as long as the number opposite to it is a comparatively small one.

The pattern on the wings and elytra cannot, of course, be the product of action near or along the muscles, as these limbs are unprovided with them internally. But it seems probable that there the sudden rush of blood and air by the accelerated circulation and respiration during the act of transformation produces the same effect. At least some patterns, the origin of which would be inexplicable, could be understood by it.

If a stream or jet of blood passing through the narrow base of the wingbag should meet within its centre a small obstacle, the previously straight stream would take the form of a funnel. Should this obstacle be a kind of ring, the funnel shape would be retained by the stream, but its central portion would pass undivided through the ring, and upon meeting another obstacle would produce a second funnel. Therefore there may be two or more funnels, one within the other, and a section of them will be circular or elliptical according to the angle at which they reach the inner surface of the wing. A curious fact seems favorably to support my suggestion. Nearly every larger ring or eye-spot of the wings shows a white interruption or spot in some place. Now as it is impossible that any obstacle, such as mentioned before, can be entirely free and isolated in the stream, we must presume that it is somewhere connected with the interior of the body, and is perhaps produced by some prominent ridge or corner, and then the funnel or the ring must be interrupted in some place by this connection. If it is so, this place will not be oxidated (colorless), and will correspond to the white spot mentioned before.

Such patterns of the elytra and wings have to be performed at the time when the wing is still an open bag, and before the transformation. There is still another circumstance which explains some patterns. The walls of the bag which will be later a wing or elytron, are very suddenly enlarged and strongly dilated during the act of transformation. Therefore small rudimentary patterns in the bag will be altered and enlarged by the same proceedings. I know that many patterns of Lepidopterous wings can be easily explained in this way. All the wavy lines and similar marks belong to these patterns. As the ribs or veins of the wings seem to grow faster in transformation than the membrane between them, the wavy shape of the lines would thus be explained. In fact the larger part of the patterns seem to be produced by expansion or by distraction of the pattern, performed in the bag at a period before transformation. It should have been stated before, that the formation of patterns on the wings of Lepidoptera must take place at the time when the scales are still little open bags.

At first my suggestion about the formation of the pattern in such a manner may seem to be strange, and perhaps not admissible. But in thinking over the subject again and again, I have found more and more support for its adoption. I had been puzzled chiefly about the existence of obstacles in the streams of blood. The excellent paper of C. Semper (Zeitschrift f. wissensch. Zool. vol. viii. pl. xv. f. 1) contains a statement of the formation of a layer to close the wing-bags at the base. This layer is formed by a number of cells united gradually by some projections, and the whole may be compared to a kind of cobweb with larger spots at certain intervals. I believe that the presence of such a layer would explain very well the presence of obstacles in the manner before stated.

A striking proof of the appearance of dark color and dark lines along an accelerated circulation is given by the dark coloration around the nipple and along the linea alba in pregnant women. This dark color is not formed by pigment cells, but by the common cells of the mucosa. Around the nuclei of these cells is found deposited fine and homogeneous pigment.

The colors of the pattern are dermal colors. They may, and in fact do, often cover the whole insect. Leydig stated long ago that the eye-spots of the caterpillars of Papilio are dermal colors. All colors, the pattern excepted, are hypodermal colors. The dermal colors are formed during the transformation, before the integument becomes rigid and before the cuticula has finished to enclose safely the colors. The hypodermal colors are formed either after this period or as a main color in previous stages just after hatching, before any pattern exists.

I think this is the proper place to mention the interesting fact called mimicry. In treating of mimicry there have been used indiscriminately very different factors. I have before endeavored to give some preliminary ideas about it, which are perhaps useful in explaining this curious fact. Of course I speak here only of mimicry in colors, of colors imitating the surroundings, as, for instance, the excrements of birds, dry leaves, berries, parts of trees, branches, bark, and whatever is found of them. The mimicry of the form and shape of other insects is even more wonderful, but still unexplained, except as a protection. I have to confess, that just the unexplained mimicry of form seems in some way opposed to my explanation of the mimicry of colors. Science is in such questions still in its infancy, and the first step is always the hardest. Every plausible suggestion is not objectionable till a more convenient one has been given.

As stated before, the dermal colors never change, the hypodermal colors can change. Therefore mimicry of pattern is here excluded, the hypodermal colors being the only ones on which the animal has any influence, either involuntarily by the constant action of the nutritive fluid, or voluntarily.

If it could be proved by facts that by a kind of photographic process the colors of the surrounding objects can be transmitted, a great step towards an understanding of mimicry in color would be attained. The fact is probable, at least in some instances. I know no other explanation, and the discovery that the seeing-purple in the eyes of men and animals retains for a certain time after death the impression of things and faces last seen, is in favor of my hypothesis. The eyes of the insects contain a layer homologous to the seeing-purple, and this layer is a decidedly hypodermal one.

There is not much known about the color of the eyes of insects. It may be said that perhaps all colors have been observed, from black to white, brown, red, blue, green, golden, and in all different shades. The color belongs to the chorioidea, and the pigment is included in cells. Eyes without color pigment do not serve for vision. As the colors are not persistent after death, they belong to the hypodermal ones. Among Arthropods is to be found, just as in Vertebrates, the peculiar organ called tapetum, a luminous colored spot on the underside of the chorioidea. The tapetum is recorded for Arachnidæ, Lepidoptera, and Diptera, and can cover the whole eye or parts of it, or can form certain figures, as in Tabanidæ and other Diptera.

Leydig describes the tapetum of fishes as formed by small plates or lamellæ in very near juxtaposition. Only by a stronger pression the iridescent lamellæ will become separated. Arthropods, for instance Chrysopa, shows in the golden eyes small colored nuclei ; but in other insects (Mantis) these nuclei alternate with iridescent plates. The large Sphingidæ and Noctuidæ possess a peculiar tapetum. A vertical cut through the eye shows underneath the dark pigment a silver-white layer with a reddish front border formed by numerous and very fine tracheæ. The reddish color belongs to the bacillar-layer of the optical nerve.

The Nature of Color and its Formation.

What is color? Where does it come from, and what part of the body is used to produce it? What kind of chemical process brings it out?

The importance of these questions is obvious, but science has not answered them till to-day. Even the questions themselves have scarcely been mentioned. It is a curious fact, though frequently observed, that the nature of the most interesting phenomena is not questioned at all, only because everybody meets them every day and everywhere.

The chemical nature of all colors — optical ones excepted — is undoubtedly proved by the fact that colors can be destroyed partially or entirely by chemical action. The greatest enemy of color is light. The strong and continuous influence of light, principally of sunlight, gradually fades every color, which is not sustained or renewed by the life of the insect. This fact is the more important, as on the other hand the influence of light during life is a color-producing one. But to produce color life is needed, for a continuous fresh supply of matter to be changed into color. As soon as life ceases and fresh matter is no longer supplied, the chemical influence of light becomes too strong, and causes discoloration.

I may here notice that Professor Sachs (Botan. Zeitung, 1863, 1865, and with Askenasy, 1867), by the examination of the influence of light in producing the blossom-colors, arrived at this result, that the development of these colors is not dependent on the influence of light. The size of the blossom and the intensity of its colors are said to depend on fertilization by insects (Wallace).* Therefore on high mountains or in northern regions, where the insect fauna is a small one, the plants have large and intensely-colored flowers, which are easily recognized at great distances. Dr. H. Müller (Kosmos, August, 1880) is of the same opinion, "that the colors of flowers are developed through the fertilization by insects, as he believes, in a progressive manner. Red, violet, and blue are always developed later, by natural selection, than white and yellow. But there is no reason

* Ch. Darwin: The Effects of Cross- and Self-fertilization in the Vegetable Kingdom, 1877.

to adopt the theory that the development of the different flower colors always originated from the same primal color, and surely the series of the developed colors was not always identical."

I am not prepared by my studies to object altogether to the statements of such prominent authorities. But it is well known that plants and animals excluded from light are more or less colorless. Secondly, the number of plants with highly colored flowers which are not fertilized by insects will exceed, perhaps largely, those fertilized by insects. The horticulturists produce year after year in greenhouses new varieties, with larger and more brilliantly colored flowers, but certainly not through fertilization by insects.

During the summer of 1881, chrysanthemums were prepared for a flower exhibition in Boston by a thoroughly experienced and scientific horticulturist. He had kept purposely plants, cuttings from one and the same plant, partly in sunlight, partly not in the dark, but without sunlight. The effect was so striking, that later the judges would not accept as a fact that both kinds came from the same stock. The plants kept in sunlight showed the most brilliant colors, the other were pale and very little colored.

I am not able to understand how this fact could be brought about without acknowledging the influence of light. I quote only this case, though every horticulturist may be able to give similar ones, because the experiment was made purposely, and is doubtless reliable. I think science will need a plausible explanation of such experiments, proving that sunlight was not the acting factor, before the statements of even such a prominent authority as Professor Sachs can be accepted.

The bleaching of the colors of insects by chloride of lime or by certain solutions of it is proved by Dimmok's experiments (Psyche, No. 17, 1875), and by my own recorded before. Perhaps chemical investigation made in a more varied manner, and the use of less strong chemicals, will some day throw more light upon the nature of colors. An interesting observation may here be noticed (J. W. Wilson: Chemical Change of Coloration in Butterflies; Psyche, No. 75, 1880). In coloring a proof plate of *Limenitis arthemis* for the well-known book by Mr. W. H. Edwards, the insect was inclosed in a shallow glass box, and Miss Peart, the artist, had fastened a bit of cotton inside with a little undiluted carbolic acid. When the plate was sent to Mr. Edwards, rich purple had been painted where the insect is metallic blue or green. The colors of the type had been changed by the acid. Several weeks later the purple disappeared, and the insect showed again its proper colors. Carbolic acid, being a comparatively weak acid, is more easily neutralized; moreover, being volatile, its effects are more transient than those of stronger acids, which change the colors. After such a change alkali only partially restores the proper colors.

The use of benzine affects mostly yellow and orange wings of Lepidoptera, changing these colors into isabell. The application of tobacco-smoke changes pink flowers of roses into light-green ones, and its effect on butterflies is visible, but less marked. Light-brown insects preserved in dilute carbolic acid become much darker, nearly blackish, and they retain this color after having been taken out of the acid.

By the chemical analysis of chitin a certain part was found apparently representing the coloring matter. It was insoluble in water, alcohol, and ether, amorphous, and probably resinous. This matter can be precipitated by acids from a solution of potash.

I was not able to find in the literature sufficient information about the chemical origin and nature of colors. Perhaps some recent publications may throw light upon the subject. Mr. M. Nencki (Bericht. deutsch. chem. Gesell. 1874, vol. vii. p. 1593) stated that indol — the coloring radical of indigo — can be produced through digestion of albumen by pancreas juice. The fact was denied by Mr. Kühne (ibid. 1875, vol. viii. p. 206), in so far as the production of indol was affirmed, but he believed it was produced by the fermentation of the juice, or by the numerous bacteriæ commonly found in the pancreas. Mr. M. Nencki reported later (ibid. 1875, vol. viii. p. 336) that he had succeeded in the production of indol from albumen only. The reddish oil — indol-coloring substance — gives with sufficient nitric acid a red color, with less a violet color (ibid. p. 722). Out of the albumen was produced 0.5 per cent nitric acid, nitrosoindol. By boiling the red coloring substance a brown one is produced, which gives in alcoholic solution of kali or natron a green color, with sulphuric acid a purple one.

In 1868 Messrs. Gräbe and Liebermann had shown that madder-lake can be obtained out of anthracen, a kind of coal-camphor. The consequence of this discovery was, that everywhere the culture of madder was given up entirely. Since that time Professor Bayer in Munich has endeavoured to produce an artificial indigo (Nature, vol. viii. p. 251; vol. xxiii. p. 390; vol. xxv. p. 593; Kosmos, 1881, vol. v. p. 61). He proved the possibility of producing it from protein bodies; but the artificial indigo would be much more expensive than the natural one. In 1878 he obtained small indications of indigo out of phenyl-acetic acid, a product of coal-tar. In 1880 he got indigo out of cinnamic acid, which is made out of toluol, also contained in the coal-tar. The cinnamic acid was changed by nitric acid into a nitrum combination, and afterwards changed by brom into dibromid. This latter in contact with alkali produces indigo. But this indigo also is more expensive than the natural one. I am not able to find more concerning the production of color in chemical literature.

All fats contained in animals and plants are glycerids of fat acids. A large series of fat acids consists always of two atoms of oxygen combined with a number of atoms of carbon, and always twice as many atoms of hydrogen. Of these acids the simplest is formic acid, (CH_2O_2), which, is common in insects, and also to be found in some plants (Urtica).

These acids are extensively developed in some insects living together in numerous societies, as in ants and white ants, but, as far as I know, not in bees or wasps. The acid is sometimes much condensed, and if one strikes a hill with the hand, it will smell strongly of acid. If in winter time, when hills are closed outside, and of course the acid in the hill is more concentrated, one tries to work with the fingers into the hill, to collect Myrmecophiles, the tips of the fingers are sometimes affected as if they had been put in very strong acids. The same is stated of tropical species of white ants living in very strongly built hills. The acid is also reported as corrosive for metals.

Uric acid is largely represented in Arthropods, and only doubtful for Arachnids and Crustacea. To the rich literature about the presence of uric acid in insects, Krukenberg,* p. 28, adds, after his own observations, twenty-eight species. It is not present in *Apis mellifica*, nor in the excrements and in the rectal glands of *Tetrix bipunctata*, of *Locusta viridissima*, and some other Orthoptera; also not in some caterpillars and in the larvæ of *Cimbex variabilis*. He never found a species which contained uric acid in the fat body, and none in the intestinal canal and in the Malpighian vessels. The insects contain, besides glycogen, leucin, tyrosin, hæmoglobin, and peptic-tryptic and diastatic enzyms.

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* C. Fr. W. Krukenberg: Vergl. physiolog. Studien an den Küsten d. Adria, 1880, 1881, vol. iii. p. 62.

Perhaps there exists some stronger acid in some insects. One observation made by myself can scarcely be explained in any other way. A large species of Mygale, having been many years in alcohol, was taken out of it and exposed on a glass slide near the stove to a moderate heat. When it was dried, I was astonished to find the whole slide injured by a corrosive acid. Examined with the microscope, the surface of the slide was covered all over with fine short and mostly parallel lines, rough as if cut out with a diamond. As there is no acid known which injures glass, fluor acid excepted, the fact cannot be explained; but I am quite sure that I was not mistaken in my observation.

I am not able to give any further statements on fat, fat acids, and other acids, because nothing more is known about them. My conclusions are as follows: —

It is certain that a color (indigo) is produced as result of the digestion of albumen.

It is certain that fat is produced by digestion out of albumen.

It is certain that colors of insects are combined with fat. Therefore it seems probable that the colors of insects are chemically produced by a combination of fats or fat acids with other acids or akalis by the influence of air, light, and heat.

It should not be overlooked that anilin is the product of a distillation of the oily parts of coal or peat. Colorless anilin has no alkaline reaction, but neutralizes acids. Everybody knows the variegated and beautiful colors originating from anilin combinations, and it is not a daring conclusion to presume that colors of animals and plants have a related origin and nature. I am assured by Professor W. Hempel, Dresden, Saxony, that in the Gulf of Naples a mollusk has been found which contains aniline colors.

The very obvious question, "Does the food have any influence on the colors of insects?" is answered as often in the affirmative as in the negative.* I have stated before that Sphingid caterpillars fed on plants placed in salt water showed colors different from the caterpillars fed with the same plant placed in fresh water. But the imago showed no difference whatever. On the other hand, the imago of the American *Hemileuca maja* shows the typical black form whenever the caterpillar feeds on *Quercus ilicifolia*, as in Massachusetts, New

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* R. MacLachlan, Entom. Weekly Intelligencer, London, 1861, No. 254: "Variation caused by the Food of the Larva does not exist."

York, and Michigan. But the pale variety, *H. Nevadensis*, occurs where the caterpillar feeds on *Spiræa salicifolia* in Maine, and probably farther in the west. The Caterpillars are slightly different in color. *Actias luna*, fed in Europe on the European walnut, is slightly different in color of the wings from those fed in America on the American walnut. The specimens from Texas are more brilliantly colored than those from New England. I have seen in the Museum in Berlin, Prussia, a large box filled with different varieties of the imago of *Bombyx caja*, and was told by Professor Klug that a number of them were artificially produced by feeding the omnivorous caterpillar with different kinds of food. The most abnormal variety came from caterpillars fed with crumbs of dry bread. Perhaps similarly reliable facts might be found in the literature. Mr. Speyer has given, as related before, some information concerning a different shade of the colors of moths which are found in America as well as in Europe. But there are probably different factors working together to produce these variations.

Krukenberg,* in his elaborate paper, "Ueber thierische Farbstoffe und deren physiologische Bedeutung," comes to the conclusion that the change of color (in perfectly developed insects) is a consequence of the change of food, and can be explained by the alteration and mutation of the pigments through heat and light. His experiments were made for the purpose of finding the cause of the turning into yellow or red by green grasshoppers in autumn. He tries to answer two questions: First, does the pigment of grasshoppers originate directly out of the food, and does it consist of pure chlorophyll or a substance containing chlorophyll, or is it to be accepted as a peculiar production of the organism? Second, is the color the consequence of only one pigment, or of several? His detailed answer is as follows:

"It is evident that the green color of the grasshoppers is the consequence of several different pigments, which can be separated by chemical process."

The immersion of the green grasshopper in ether colors it yellow, and the grasshopper becomes cochineal red. The same is observed when insects are treated with hot water or alcohol. The turning to cochineal red is not the consequence of a chemical mutation of the yellow-green pigment, but solely of its extraction, and the subsequent

* C. Fr. W. Krukenberg: Vergl. physiolog. Studien an den Küsten d. Adria, 1880, 1881, vol. iii. p. 62.

appearance of the red color, which was formerly covered. If the grasshopper or its wings are subjected to stronger heat, both pigments disappear at the same time. Krukenberg believes it to be very probable, after his experiments, that the light has a prominent influence on the color of insects, and that the light turns to red the insects which were green during the summer. Spectral analysis makes it evident that the green color has no connection with chlorophyll.

It is often denied by entomologists that food has any marked influence on color, as it is observed that in many cases caterpillars of the same species feeding on the same plant show very different colors, as, for instance, many Sphingidæ, cankerworm, and others.

Perhaps *Coccus cacti* derives its coloring matter from the cactus; but I was puzzled to find that some grubs of a beetle from Peru, preserved in alcohol, had colored the alcohol rather intensely with cochineal color. I do not know whether they live on the cactus, but it can hardly be presumed. That other insects prepare a coloring matter is well known from the May-beetles in Europe. An umber-brown color, good for use, was prepared from them by distillation, and used at the end of the last century. Mr. G. B. Buckton * and Mr. Sorby † have published very interesting notes and experiments upon the coloring matter of the Aphides. The somewhat condensed conclusions are: —

1. The purple coloring matter appears to be a quasi-living principle, and not a product of a subsequent chemical oxidizing process. Mounted in balsam or other preserving fluids, the darker species stain the fluid of a fine violet.

2. As autumn approaches and cold weather reduces the activity of the Aphides, the lively greens and yellows commonly become converted into ferrugineous red, and even dark brown, which last hue in reality partakes more or less of intense violet or purple. These changes have some analogy with the brilliant hues assumed by maple and other leaves during the process of slow decay.

3. Aqueous solution of crushed dark-brown and yellow-green varieties of Aphides originate different colors with acids and alkalies. The chief difference consists in an alkali changing the solution of green Aphides into a gamboge-yellow, instead of a purple, as in the brown Aphides.

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* G. B. Buckton: Monograph of the British Aphides, vol. ii. p. 167. London, 1879.

† Sorby: On the Coloring Matter of some Aphides. Quart. Journ. Microsc. Soc. vol. ix. p. 352. London.

4. In the generality of cases coloring matters, such as indigo, Indian yellow, madder-lake, and the like, do not separately exist in the substance of vegetables, but the pigments are disengaged through fermentation or oxygenation. Again, alizarin itself is reddish yellow, but alkaline solutions strike it a rich violet, just as we find them act towards the substance which Mr. Sorby calls Aphidilutein.

5. Mr. Sorby's four stages of the changes effected by the oxidation of Aphideine produce four different substances.

The different colors produced by the use of different chemicals must be compared in Mr. Buckton's paper. But there can be no doubt that here colors are produced chemically out of protein-bodies, — a fact somewhat homologous to the before-quoted artificial production of indigo.

The influence of temperature on the colors of the imago of Lepidoptera was first shown by Mr. Dorfmeister. He proved that a higher temperature changes the reddish-yellow of the hind-wings of *Bombyx caja* to minium, a lower temperature to ochreous yellow. The changing of spring-races of butterflies into autumn-races by putting the chrysalis on ice, the well-known experiments made by Mr. W. H. Edwards and Prof. Weismann and others, show unquestionably the influence of temperature on colors. Probably here the change is the effect of a surplus of nitrogen. The water absorbs a small quantity of air, but in such a manner that this air contains less than two parts (1.87) of nitrogen to one part of oxygen, instead of four parts of nitrogen. Therefore an excess of nitrogen in the surrounding air must be the consequence, as is the case in the iced chambers of fruit-houses, where the oxygen is purposely rarefied in relative quantity. By this nitrogen, together with the nitrogen contained in the chrysalis, life and development are retarded to a minimum; but the chemical action which produces colors will work nevertheless to a certain extent. Therefore a change in the colors of the imago is the necessary consequence, and this change affects probably the pattern, which is, as stated before, produced largely by oxygen, which is here rarefied.

Goethe has characterized the yellow and related colors as acid ones, the blue and related as alkaline colors. He states that vegetable yellow colors can be changed by alkali into red, or even into blue red.

For plants the predominant color is green, for insects brown; both of which are called indifferent colors.

Final Conclusions.

If color and pattern are produced in a purely mechanical manner, as Prof. Weismann contends, it ought to be possible to explain and to prove this mechanical manner, if we will go beyond the simple belief that it is so.

The foregoing review contains all that is known about these questions: —

1. That some colors of insects can be changed or obliterated by acids.

2. That two natural colors, madder-lake and indigo, can be produced artificially by the influence of acid on fat bodies.

3. As protein bodies in insects are changed into fat bodies, and may be changed by acids contained in insects into fat acids, the formation of colors in the same manner seems probable.*

4. That colors can be changed by different temperature.

5. That the pattern is originated probably by a combination of oxygen with the integuments.

6. That mimicry of the hypodermal colors may be effected by a kind of photographic process.

In comparing these still insufficient data with the statement — that color and pattern are produced in a purely mechanical manner, and are the consequences of natural selection, of adaptation, and of inheritance, — we must, if we wish to go beyond belief, directly exclude inheritance, as after the statement of Professor Weismann himself † it is entirely unknown how inheritance works; even the question itself is still entirely untouched. We must further exclude natural selection and adaptation, as both are (according to Professor C. Semper ‡) only able to begin to work after pigment is produced and after a change of the pattern has begun.

What is then left to justify our accepting a purely mechanical manner but the simple belief that it is so?

I am convinced that color and pattern are produced by physiological processes in the interior of the bodies of insects.

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* Dr. R. Sachse: Die Chemie und Physik der Farbestoffe, Kohlenhydrate u. Proteinsubstanzen, p. 288 sqq. Leipzig, 1877.

† Dr. A. Weismann: Die Dauer des Lebens, 1882; and Studien, vol. ii. p. 296.

‡ Professor C. Semper: Die natürlichen Existenz-bedingungen der Thiere, 1880. Vol. i., p. 205; vol. ii. p. 232.

XV.

ON TELEPHONING OVER LONG DISTANCES OR THROUGH CABLES.

By N. D. C. Hodges.

Presented May 10, 1882.

The first point I wish to bring up is, that within any conductor connected with the earth the only electrical forces against which work has to be done during the movement of electrified bodies are those due to the mutual actions between the charges in these bodies, and not to the charges which may exist outside the conducting surface. So that in causing a movement of electricity from A to B, the work is the same when A and B are inside a conducting surface as when they are outside; and to cause a current along any course from A to B, the same amount of energy will be required as if the system $A\ B$ were in open space.

Hence in the case of a double-wire cable of no great length compared with its section, so that the resistance of the wire should not be sufficient to cause it to act like a succession of short pieces, the source of the electromotive force being contained in a conducting surface continuous with the outside of the cable, a current could be produced as easily as in an air-line.

In the next place, in the case of a cable we have a condenser to deal with, the circuit wire being the inner, and the water outside the outer surface. In order to cause a current to flow through a conductor situated in this way, a quantity of electricity must be supplied sufficient to raise the potential along the conductor to such a degree that the required current may flow.

To raise the charge of a conductor, the work to be done is expressed by $\frac{1}{2}\ \varepsilon V$, where ε is the final charge of the conductor and V its potential; or, in terms of the capacity and potential, $\frac{1}{2}\ q\ V^2$.

For a single wire surrounded by a homogeneous non-conductor to an indefinite distance, the electric capacity is $\frac{1}{2}\,\frac{l}{\log \frac{l}{a}}$, where l is the length of the wire and a its radius.

For a wire surrounded by a homogeneous dielectric to a limited distance, the capacity is $\frac{1}{2}\,\frac{Kl}{\log \frac{a_1}{a_2}}$, where K is the specific inductive capacity of the dielectric, and a_1 and a_2 the outer and inner radii of the dielectric.

As the energy required to charge a condenser is

$$W = \tfrac{1}{2}\, q\, V^2,$$

and as no work is done in moving the one conducting surface within the other, the same expression for the work done in charging a cable will hold when the wire is not concentric with the outside as when it is, as was supposed in the above.

Hence the work required to charge a unit length of cable, even when the wires are not in the centre, will be equal to

$$W = \tfrac{1}{2}\, q\, V^2 = \tfrac{1}{2}\, \frac{K}{\log \frac{a_1}{a_2}}\, V^2.$$

On account of this static capacity of a cable, there is a retardation in the transmission of signals from the greater amount of energy which must be supplied from the electrical source before the potential along the wire will be raised sufficiently to cause the required current; just as, in the case of heat, the specific heat of a bar determines how much heat must be given to one end of the bar before heat will flow along the bar at any given rate.

With a single wire cable let V be the potential at any point of the wire. Let Q be the total quantity of electricity which has passed through a section of the cable at that point since the beginning of the current. Then the quantity which at the time t exists between sections at x and $x + \delta x$ is

$$Q - \left(Q + \frac{dQ}{dx}\,\delta x\right) \text{ or } -\frac{dQ}{dx}\,\delta x$$

and this is equal to $q\,V\,\delta x$.

Hence $$q\,V = -\frac{dQ}{dx}.$$

With a double-wire cable when used to form a metallic circuit, the two wires being connected to the two poles of the battery or transmitter, or whatever the electric source may be, the quantity of electricity flowing across any section of the cable on one of the wires will be equal and of opposite sign to that on the other.

Hence the total quantity flowing across any section of the cable will be zero, and dQ will be zero. So that the potential to which the condenser, consisting of the two wires and the outside surface of the cable, will be raised will be zero, and the energy required from the battery no greater on account of the nearness of the water, the second conducting surface of the condenser.

There is one thing to be considered, that the wires, being covered with some insulating material which cannot be made perfectly homogeneous, they, with the broken nature of the dielectric about them, will each form a condenser to some extent.

It would therefore appear that, as far as the retardation is due to the static capacity of a cable, it can be greatly reduced by using a double wire cable with homogeneous insulating material.

In support of this view there are the experiments made by Wheatstone, and described in the Proceedings of the Royal Society for 1854–55. Wheatstone made experiments on a cable of six wires intended for use in the Mediterranean. The length of the cable was one hundred and ten miles. On connecting one of the wires with one pole of his battery, the other pole being to ground, he found that quite a time was required before the flow into the cable fell to the rate due to leakage. On connecting one pole of the battery with one wire and the other with another, the charge which the cable wires would take was reached instantly.

On long land lines the static capacity of the line is due, outside of the capacity of the wire, to the neighborhood of the earth. This has been found to affect the articulation in telephoning on the line from Boston to Baltimore, five hundred miles in length. By the use of a complete metallic circuit the articulation was greatly improved.

Salem, Mass., U. S. A.,
May 9th, 1882.

XVI.

ON THE YOUNG STAGES OF SOME OSSEOUS FISHES.

By Alexander Agassiz.

Presented May 9, 1882.

Part III.*

Many interesting points of relationship between the embryos of osseous Fishes and their fossil representatives have been traced by comparing the structure of the tail of the fish embryo as it passes from the leptocardial stage through the various stages of heterocercality to a so-called homocercal stage. This relationship, as has been pointed out, is very marked, and has led to some important generalizations. The comparison of the pectorals or of the dorsal and anal fins does not, however, lead to such interesting results. It is true that as far as the pectoral fins are concerned, their resemblance in the early stages of the bony fish embryo to the crossopterygian type of pectorals is very striking, but, owing to our imperfect knowledge of the structure of the pectorals of the ancient Fishes, this comparison is at present less complete than that between the tails of the older fossil Fishes and the tails of the embryos of the modern osseous Fishes.

With regard to the comparison of the median fins of the osseous Fishes of to-day with the median fins of Fishes of earlier periods, we do not come to any satisfactory results. If we take, for instance, the change undergone by the embryos of osseous Fishes, we find invariably in the youngest stages a continuous embryonic fold, extending from the head along the dorsal side to the extremity of the tail and around the lower side to the yolk bag. At a later period, when they carry embryonic rays, these embryonic median fins resemble somewhat the

* Part I. Proc. Amer. Acad. XIII. 1877–78, p. 117; Part II. Proc. Amer. Acad. XIV. 1878–79, p. 1.

fins of some of the earlier Ganoids in which the fin rays are very numerous, as, for instance, the Platygnathus of the Old Red. These characters are represented in the Ganoids of to-day both in Ceratodus and Protopterus; indeed even the Blennies, Eels, Murenidæ, and Ophididæ of to-day may be regarded as types of these embryonic stages, of which Phaneropterus with its confluent dorsal and caudal is a representative among the older fossils. But in the one case the fin rays are the permanent rays, while in the other the [embryonic] fin rays disappear with the appearance of the permanent osseous fin rays, as I have shown in my paper on the early stages of Lepidosteus.* The same conditions are repeated also in the young stages of that genus.†

As regards the formation of the dorsals, the posterior dorsal is the first to be differentiated; in the embryos of the osseous Fishes the anterior dorsal appearing only subsequently, and either independently or connected with the posterior one. In those fishes which have these fins separated in the adult, the dorsals are usually united in the earlier stages, but if the anterior dorsal is of a peculiar type, as, for instance, in Lumpus, Trachypterus, and Lophius, the anterior dorsal becomes separated at an early stage, sometimes even while still in the egg, from the posterior dorsal. We can therefore assume that as far as the dorsals are concerned a continuous median fin still connected with the caudal is the earliest embryonic type of fin.

The next stage of development is a type in which the caudal is well separated from the dorsal and anal embryonic fold, with a continuous single dorsal ending finally by the differentiation of the dorsal into one or more independent dorsals. The formation of abnormal types of anterior dorsal to form structures adapted to special uses, as in Lophius, is an embryonic feature, and this development of the dorsal may exist either as a separate dorsal, or the anterior rays of the single dorsal may be developed to an extraordinary degree, forming immense filaments, as in Argyreiscus, Blepharis, and many other fishes.

This anterior dorsal also may exist only in the embryonic stage, as is the case in Fierasfer and Trachypterus. The anal is usually well developed before the appearance of the ventrals, except in the cases of those genera in which the ventrals take an extraordinary development

* Proc. Amer. Acad., 1878, XIII. p. 65.

† In my next paper on bony Fishes, I hope to treat of the transformation of the median fins of osseous Fishes from their embryonic stage to that of fins with permanent osseous rays.

and are adapted for special uses, as in the young of some Gadoids, or those genera in which the rays of the ventrals extend into large filaments, which may be of use as tactile organs. The most characteristic of these genera are found among some of the newly discovered deep-sea Fishes dredged by the "Challenger" and by the "Blake."

In the Fishes living at moderate depths and in pelagic Fishes the pectorals or ventrals may be developed into organs of flight, as we find it to be the case in the young of Onus, which certainly mimics to an extraordinary degree in its embryonic stages the Flying-Fishes. The specialized ventrals of the embryonic stages of Lophius and Onus may represent the huge ventral appendages, articulated fins, which exist in Pterichthys and other Devonian Fishes. The absence of ventrals or the presence of small ventrals and the existence of a large anal fin, still more or less united with the caudal and dorsal fin, may thus be regarded as embryonic characters. The differentiation of the anal is the next stage of development, and well-developed, isolated anals and ventrals are generally found to occur with well-developed and isolated dorsals. The existence of abnormally developed ventrals, as in young Gadoids, may also be considered as an embryonic character.

As far as the oldest fishes are concerned, we find in them the same dorsals and anals isolated from the heterocercal tail fin, just as they exist in many of the Fishes of the present day, and there is nothing to show that in the earliest known fossil Fishes the development of the median fins did not take place much in the same manner as it takes place to-day in the young of Lepidosteus.

There is something in the general structure of the youngest embryos of Lumpus which recalls to us the Cephalaspidæ. The position of the mouth in all young bony Fishes is characteristic of the earliest Fishes; they have in common also a cartilaginous skeleton, heterocercal tails, and a rudimentary dorsal and anal, with prominent pectorals, as in some of the fossil genera. With the Dipteridæ, although we have median fins broken up into several distinct fins and a heterocercal tail, yet these fins all belong to the embryonic posterior dorsal and anal. In the next prominent group, the Acanthodida, the heterocercal tail continues and is found to exist with single anal and dorsals, and small ventrals with well-developed pectorals. While in the Palæoniscidæ, the Dapedidæ and Pycnodonts, we find the representatives of embryonic types in which the tail becomes much less heterocercal, the anals and dorsals are each one long continuous fin with numerous rays, recalling the embryonic stages of Poronotus figured in this memoir. When, however, we reach the Jurassic, Cretaceous, and Tertiary, we come upon types more closely allied to the older stages of our bony Fishes, embryos in which an anterior dorsal is found, of which the anterior part is more or less developed, as in *Platax semiophorus* and the like, having also heterocercal tails. We also meet in these later formations genera in which the fin rays of the ventrals are still excessively developed, as in embryo Gadoids, and finally find the Fishes of the youngest formations agreeing more closely than any of their predecessors with the adult forms found in the seas of the present day.

The number of scattered papers in which various young stages of osseous Fishes are described is large, but, with the exception of the memoirs of Sundevall, of Lütken, and of an interesting chapter on Young Fishes by Günther in his Introduction to the Study of Fishes, these papers are usually limited to a single stage of development. As the present communication is mainly devoted to the study of young stages which have not as yet been described, I have quoted only those papers which had special reference to the genera here studied. I propose to incorporate the bibliography covering this subject with that of the Embryology of Fishes now in preparation for the "Selections from Embryological Monographs" to be published in vol. ix. of the Memoirs of the Museum of Comparative Zoölogy.

Labrax lineatus. *Bl. & Sch.* (*Roccus,* Gill).

(Plate I. Plate II. figs. 3, 4.)

In very young striped Bass, measuring about 3.5^{mm} in length (Plate I. fig. 1), the eye is of a bright blue color, with an emerald green band above the pupil. This, with the prominent silvery swimming bladder and the long line of large chromatophores extending from the vent along the base of the embryonic anal fin nearly to the extremity of the body, renders it easy to recognize the young stages of the Bass. All the stages here figured were collected on the surface with the tow-net. The eggs I have not found.

In the next stage (Plate I. fig. 2) the head has become proportionally larger, the mouth is placed more anteriorly, and the embryonic caudal rays are also more prominent. The muscular bands, the brain as well as the stomach, are colored a light yellowish brown.

In the next stage (Plate I. fig. 3) the head is comparatively still larger, the body has become stouter, and the embryonic caudal is better separated from the dorsal and anal fin folds. The jaws are larger, the lower jaw projecting well beyond the upper one. In the next stage (Plate I. fig. 4), the permanent caudal is forming, and the original muscular bands around the body are more distinct than in the previous stage, otherwise the young fish does not differ materially from the stage of Plate I. fig. 3. In the next stage (Plate I. fig. 5) the caudal is almost terminal, and the posterior dorsal as well as the anal are indicated by the rudimentary permanent rays along the dorsal and anal lines.

In Plate II. fig. 3, the young Bass has a symmetrical rectangular caudal, well-developed pectoral and ventral fins, with anal and posterior dorsal completely separated from the caudal, the permanent rays large. The anterior dorsal is low, and still united with the posterior dorsal; the line of pigment spots extending along the ventral side is the only prominent one. A young Bass in the stage of Plate II. fig. 4, shows a forked caudal comparatively larger than in the adult, while the outline of the dorsal and anal is lobed, and the anterior dorsal distinct from the posterior one, and fully as high. The head has also become more elongated, and the little Bass assumes somewhat the coloring of the adult. In addition to the original ventral line of pigment spots, two prominent stripes of elongated black spots extend along the lateral line, and a less distinct line runs along the base of the dorsals. The line at the base of the dorsals is sometimes present in much younger specimens (Plate I. fig. 3 *a*) not older than those of Plate I. fig. 3. In a younger stage than Plate I. fig. 3 *a*, this dorsal line was interrupted, consisting of three patches along the base of the dorsals. The pigment spot which appeared at the base of the caudal rays as early as in stage Plate I. fig. 2, now extends as a short line across the base of the permanent rays.

TEMNODON SALTATOR, *Lin.* (*Ponatomus saltatrix*, Gill).

(Plate II. fig. 5.)

Of the Carangidæ I have only found on the surface one small Blue fish (Plate II. fig. 5) measuring 9^{mm} in length. The tail fin was but slightly forked; the anterior dorsal rudimentary, but the base of the permanent fin rays already present; permanent fin rays existing in the posterior dorsal as well as the anal; large pectorals, rudimentary ventrals. Teeth of upper and lower jaw already quite prominent; body elongate, angular. Prominent line of black pigment spots extending from the top of the head to the end of posterior dorsal along upper side of stomach and base of anal and caudal. Eye bright blue, bluish silvery body with a few faint pigment cells uniformly scattered over the flanks. The Carangidæ with rudimentary ventrals and no anterior dorsals are evidently genera representing the embryonic stages of this family.

STROMATEUS TRIACANTHUS, *Peck* (*Poronotus triacanthus*, Gill).

(Plate VI.)

The more advanced stages of the Butterfish (from 10–20^{mm} in length and larger) are frequently found within the tentacles of our common Dactylometra. The younger stages were, however, all fished up from the surface with the hand-net.

The youngest stage of Poronotus observed measured 7^{mm} in length (Plate VI. fig. 1). The body in this stage is comparatively stout, the head large. The caudal is already developing, though the embryonic lobe is still present; the urostyle is quite large. The dorsal and anal embryonic fins are narrow. The pectoral is large, rounded, transparent, the permanent rays well developed. The eye is large, and has the peculiar greenish-brown metallic lustre of the adult; this makes it comparatively easy to recognize the embryo Butterfish in the early stages.

There is a line of large chromatophores along the base of the anal, extending from the vent along the ventral line to the operculum, a few large pigment cells (four to five) on the digestive cavity, and a large patch over the swimming bladder. There are four comparatively small pigment cells along the lateral line, three to four along the dorsal line behind the head, and eight to ten irregular pigment spots on the head above the eye, with three or four small pigment cells in advance of the eye and on the jaws. In the following stage (Plate VI. fig. 2) the anterior part of the body and the head have a light brownish tint, the tail fin is nearly symmetrical, it has permanent fin rays with three articulations, the body is somewhat more elongated, there are the first traces of the permanent dorsal and anal fin rays along the dorsal and ventral lines. The general distribution of the pigment spots is very similar to that of the previous stages; the cells are, however, somewhat more dendritic. In the following stage figured (Plate VI. fig. 3) the chromatophores have greatly increased in number and size, especially on the upper part of the head and along the flanks of the anterior part of the body. There is now a double line of dendritic cells extending along the base of the anal and of the dorsal, and a few small cells at the base of the caudal rays. The dorsal and anal fins are separated from the caudal by a deep cut, but the caudal embryonic fin fold is still quite broad, and extends well beyond the base of the tail.

In the next stage (Plate VI. fig. 4) the young Poronotus has assumed, though faintly, the general coloring of the adult. The whole body is slightly tinted with yellowish brown, the head and anterior part of the body being darkest, with patches of carmine between the eye and base of the brain. The upper part of the head, the anterior part of the dorsal line, and the flanks of the body are well covered with large dendritic chromatophores closely packed together. Large and more distinct cells cover the sides of the body behind the digestive cavity. A row of longitudinal bars of pigment extends along the whole base of the dorsal, while delicate dendritic cells extend along the base of the anal and at the base of the caudal rays. The caudal in this stage has become slightly forked, the dorsal and anal are high, still better separated from the caudal than in the previous stage. The mucous pores of the head are already quite numerous along the operculum and near the nostrils. When the young Butterfish has reached a length of 16^{mm} (Plate VI. fig. 5) the body has become much broader, the mucous pores of the head have greatly increased from the previous stage figured, the chromatophores of the anterior part of the body, above the head, along the dorsal region, and over the stomach have become very numerous, they extend over the anterior part of the dorsal, with a double line of rectangular spots along the base to the extremity, and a similar double line extends along the base of the ventral. The dorsal and anal, as well as the caudal, have assumed very nearly the outline they have in the adult; the permanent rays are well articulated in the median fins.

Atherinichthys notata, *Günth.* (*Chirostoma*, Gill).

(Plates X., XI.)

The youngest specimens of Atherina (Plate X. fig. 1) are striking for their coloring, a light yellow tint extending over the whole embryo. The young Atherina is readily recognized from its light-blue eye, with greenish-emerald band above the pupil, and large otoliths, the patches of large chromatophores along the upper and lower side of the stomach, and three lines of rectangular pigment cells extending, the one along the whole base of the embryonic anal, the second along the lateral line, the third along the base of the posterior extremity of the embryonic dorsal. The next stage figured (Plate X. fig. 2) is characterized by its proportionally larger head, by the presence of a large dendritic pigment cell over the base of the brain, with five rounded spots in front of it over the principal lobe of the brain, and similar spots behind extending into the dorsal line of pigment spots, which in this stage runs along the whole base of the embryonic dorsal, and forms a line fully as marked as the other two already existing in the younger stage. In this stage the yellow coloring of the body is more intense along the upper part of the head, over the stomach, and along the dorsal line, than in the younger stages. The large dendritic pigment cells on the top of the head are sometimes found in specimens quite as young as Plate X. fig. 1. In the stage of Plate X. fig. 2, the caudal fin is forming.

In the next stage figured (Plate X. fig. 4) the head has become somewhat lengthened, the caudal fin more terminal, the embryonic caudal lobe quite rounded; the yellow coloring of the body and head is more marked, and has assumed at the same time a somewhat greenish tinge. The embryonic dorsal and anal are slightly lobed; the first trace of the base of the permanent dorsal and anal rays can be seen along the dorsal and ventral lines. There are very rudimentary ventrals as slight projections, one on each side of the anterior part of the embryonic anal. The diagonal muscular bands are well marked. The three lines of pigment cells are more prominent than they were in the preceding stage.

In a somewhat older stage (Plate XI. fig. 5) the head is proportionally more elongate than in younger stages. The caudal fin is nearly symmetrical, but with a slight trace of the embryonic caudal lobe; the dorsal and anal are well separated from the caudal; their permanent fin rays have commenced to form, though not as well advanced as those of the caudal.

In the next stage figured, when the young Atherina has attained a length of about 16^{mm} (Plate XI. fig. 6), the general outline of the head and body is much that of the adult; but the tail fin is still rounded; there is but a trace of the anterior dorsal; the dorsal and anal are still quite low, though completely separated from the caudal; the anterior part of the anal embryonic fin, in which no permanent rays are formed, has not entirely disappeared; the ventrals have greatly increased in length since the stage of Plate XI. fig. 5. The caudal rays are edged with rows of narrow pigment cells, while in the preceding younger stage the pigment spots of the caudal were limited to the base of the rays (Plate X. figs. 3, 4), or there are but a few irregularly scattered along the fin rays (Plate X. fig. 5). There is a marked line of pigment cells along the base of the dorsal and anal; in the anal an additional line of pigment spots runs near the outer edge of the fins. The general coloring of this stage approaches quite nearly that of the adult, though the body and the lateral line do not have quite as silvery a lustre as in the older stages.

In the oldest Atherina here figured the snout has become quite pointed (Plate XI. fig. 7). The anterior dorsal has made its appearance, the caudal is forked, the dorsal and anal are high, having much the shape they have in the adult, the pectorals are quite pointed. The permanent rays of all the fins are now edged with narrow pigment cells. The pigment spots of the lateral line consist of three or four irregular lines of minute dendritic chromatophores, while the dorsal line is made up of two irregular lines of large spots extending from the snout to the base of the tail. The ventral line extends only from a point slightly in advance of the base of the anal to the caudal fin; it also consists, like the dorsal line, of two irregular lines of elongated pigment spots. In this stage the young Atherina has fairly assumed the principal characteristic features of the adult.

Batrachus tau, *Lin.*

(Plate XVI. fig. 1.)

Dr. Storer has given a figure of a young Batrachus (Mem. Amer. Acad. v., Plate XIX.) measuring about 2^{mm} in length. It differs but slightly from the large specimens, the more rounded outline of the head, as seen from above, and the greater elongation of the head characterising this younger stage.

A young specimen (Plate XVI. fig. 1), measuring only 8^{mm} in length, was slender, the pectorals fully developed; the openings in the mucous membrane of the head were well developed, the ventrals small; the dorsal and anal fins were still connected with the embryonic caudal, the separation between the anal and caudal being but little marked. The tail fin was still in an embryonic stage, with a well-marked trace of the ganoid lobe. The whole fish was dotted with small pigment spots, with a few larger cells scattered irregularly over the surface; the pectorals were similarly covered. The general tint of body and fin was gray, with blackish and yellowish pigment cells.

Lophius piscatorius, *Lin.*

(Plate XVI. figs. 2–5; Plates XVII., XVIII.)

The eggs of Lophius are laid embedded in an immense ribbon-shaped mucous band, from two to three feet broad and from twenty-five to thirty feet long. This gelatinous mass is often found floating on the surface of the sea during the last part of August. It looks at a short distance like an immense crape. The mucous mass is of a light violet gray color, and the dark black pigment spots of the young Lophius, still in the egg, give to the mass a somewhat blackish appearance. The eggs are laid in a single irregular layer through the mass, usually well separated by the mucus in which they float (Plate XVI. fig. 2).

When just hatched (Plate XVI. fig. 4) it would be difficult to recognize the young as the embryo of Lophius. It has but a single first dorsal element, a narrow short spathula-shaped ventral, and a small circular pectoral. These characters, with its transversally flattened body and head, seem in this stage to have no relation to the vertically flattened adult Lophius. The embryo in this stage, as well as while still in the egg (Plate XVI. fig. 3), and until it is far more advanced (Plate XVI. fig. 5, Plate XVII. fig. 7), is remarkable for the great width of the embryonic fin fold along the dorsal and ventral lines, the very straight notochord, and the three or four prominent patches of intense black pigment cells placed at equal distances along the lower, upper, and terminal parts of the chord. The tail pigment spots extend on both sides of the notochord, and form the largest of the three patches. This is the case from the earliest stages, until the body of the young Lophius is completely covered by pigment cells, as in the oldest stage here figured (Plate XVIII. fig. 2). I have already on a former occasion figured some of the changes which the tail undergoes as the embryo passes from the stage of Plate XVII. fig. 3, to the oldest stage of the young Lophius (Plate XVIII. fig. 2).

The principal changes of form of the body of the young Lophius consist in the gradual flattening of the head, and at the same time the increase in the proportion of the head as compared to the rest of the body, — a feature in which Lophius and the Cottoids differ somewhat from the post-embryonic changes of other osseous Fishes, where the head loses in later stages the comparatively huge size which characterizes nearly all the younger stages of bony Fishes soon after they leave the egg.

The yolk bag of the young Lophius when just hatched is comparatively small (Plate XVI. fig. 4), being almost entirely absorbed while still in the egg, and it soon disappears entirely (Plate XVI. fig. 5). In a somewhat younger stage, taken out of the egg (Plate XVI. fig. 3), it is quite globular, and the first trace of the pectorals and of the ventrals as a mere fold of the embryonic fin fold, which extends over the yolk bag, is still well shown.

In these earlier stages (Plate XVI. fig. 3, and Plate XVI. fig. 1) the embryonic fin folds are covered with minute round black pigment spots. It is only in much more advanced stages (Plate XVIII. fig. 1) that we begin to find traces of the ordinary dendritic pigment spots which eventually cover the dorsal, anal, and caudal fins (Plate XVIII. fig. 2).

The young a few days after hatching (Plate XVI. fig. 5) differ from the preceding stage mainly in the greater elongation of the head, the disappearance of the yolk bag, the comparatively larger pectorals, and in the position of the eye, which is somewhat higher. In the next stages (Plate XVII. figs. 1–3) the head has become still more elongated, the lower jaw projects well beyond the upper jaw, the branchiæ are well developed, the eye has assumed a still higher position in the head, the pectorals have greatly increased in size, the single anterior dorsal element is more than double what it was in the size figured before, and the ventrals have become greatly lengthened, showing a trace of the second ray at the base of the larger ones. The alimentary canal is well circumscribed, and the pigment spots over the remainder of the yolk bag, the top of the brain, and the base of the chorda are of an intense black, with a slight tinge of yellow over the alimentary canal.

The outline of the body has somewhat lengthened, the embryonic dorsal and ventral fins remain of great width, showing as yet no trace of separation of an anal or dorsal or caudal fin, beyond the presence of embryonic fin rays in the large caudal pigment spot (Plate XVII. fig. 3), already present in younger stages.

In somewhat older stages the original dorsal ray shows a trace of a second ray behind its base (Plate XVII. fig. 4), which in a still older stage attains half the length of the original ray (Plate XVII. fig. 5.). The second ray of the pectorals of this same stage (Plate

XVII. fig. 4) has also greatly increased in length from that of Plate XVII. fig. 3, the original pectoral ray at the same time having become so bent that the extremity forms an obtuse angle with the base. The separation of the anterior from the posterior dorsal takes place at a very early stage, already within the egg (Plate XVI. fig. 3), the first ray of the anterior dorsal pushes its way through the embryonic dorsal fold in a slight depression formed above the head, and thus forms the separation of the anterior part of the dorsal embryonic fold from the posterior. In a view from above of the young Lophius within the egg, the derivation of the pectorals and of the ventrals from the embryonic fin fold which covers the yolk bag is well seen. The paired fins are formed in the same manner on the yolk fold. They belong to the original embryonic fin fold, which splits, so as to cover the yolk bag.

Plate XVII. fig. 6, represents the embryo Lophius in a somewhat older stage than when the dorsals and ventrals are in stage figured on Plate XVI. figs. 4, 5. The dorsal and ventral embryonic folds are somewhat more opaque, both from the greater number of pigment spots, which, however, are of lighter tint than in younger stages, and from the additional number of embryonic fin rays. These are now very closely placed together on the dorsal side; they are somewhat less numerous and more distant on the ventral side. This stage is remarkable also for the great size of the lobed fleshy pectorals, with rows of light gray dendritic pigment cells along the line of the embryonic rays. There is a rudiment of a third dorsal ray, and the second ray of the ventral is more than half as long as the original ray. Teeth are well developed on the lower jaw. In the next stage figured (Plate XVIII. fig. 1) the principal differences consist in the increased length of the anterior dorsal rays (there are three rays now, and the rudiment of a fourth), the increase in length of the two ventral rays and the appearance of a rudiment of a third ray. Muscular bands are now more distinct along the body than in the younger stages; the three principal pigment spots have become broken up into smaller dendritic pigment cells, and we have the first trace of the formation of a caudal fin in the widening of the body immediately below the anterior part of the caudal pigment spots. The fleshy pectoral has become still larger than in the last stage figured; the dendritic stellate chromatophores of the head and of the ventral region of the pectoral side of the body are more numerous; the head has greatly increased in size, it is colored light yellow; the muscular bands and the tissues below the patches of the chromatophores along the body line are of the same color. The broad flat fin rays, dorsal and ventral, are of a grayish tint; the eye is blue. In the oldest of the young Lophius which I have had occasion to examine (Plate XVIII. figs. 2, 3) the changes from the preceding stage are very great. Although the body is still laterally compressed, the head, which has greatly increased in size, as well as the body anterior to the anal opening have become somewhat flattened vertically, the first trace of the great flattening so characteristic of the genus. The anterior part of the head projects proportionally far in advance of the orbits, the head sloping less from the base of the anterior dorsal ray than in preceding stages. The pectorals have now become enormous, they extend across the whole width of the body of the young Lophius, they are lobed at the edge, the rays articulated, well marked, and edged with rows of elongated dark pigment spots. The tail fin is well formed, though it still retains its ganoid shape, and the posterior dorsal and anal, though well formed, are still connected by a distinct remnant of the dorsal and ventral embryonic fin fold with the caudal fin. The anterior dorsal now has five rays, with a rudimentary one anterior to the first formed ray. These rays are connected at the base by a fin fold at a much higher point than in younger stages; they extend far beyond the fold; the extremities curve down about a quarter of the length of the ray. The increase in length of the ventral rays has been still more remarkable. The original ventral ray is now nearly twice as long as the body of the fish, and the second ray extends fully as far as the extremity of the caudal fin. There are two shorter exterior rays and one interior ray; they are joined by a membrane extending nearly to the base of the caudal, so that when expanded and seen from above the ventrals appear like regular wings. Their great size and the shape of the peculiar pectorals is well seen in the figure from above (Plate XVIII. fig. 3). The general color of the body of the largest specimens here figured is of a very light, dirty violet tint, of an olive green along the dorsal line; the body and head are covered by darker violet gray pigment spots. The pigment spots of the ventrals are of an intense black, as well as a few of the spots along the extremity of the urostyle. The pigment cells, of a violet gray, are especially numerous along the line of the pectoral rays, with a row of darker cells at their base (fig. 10). The dorsal, anal, and caudal fins are still very transparent, with a delicate tinge of violet. The young Lophius is very active during its embryonic stages, in striking contrast to the sluggish habits of the adult. The adult is comparatively a deep-water fish. I have dredged it in the "Blake" as low down as 320 fathoms off Newport. The females undoubtedly come to shallower waters to spawn, as they are not an uncommon fish during July and August, being frequently found left by the tide on the flat where they come to spawn.

The young in the stages here figured are pelagic Fishes; they were all collected, during July, August, and September, on the surface both at Newport and in Massachusetts Bay. The young hatched from the egg were only raised as far as the stage represented in Plate XVI. fig. 4. The young fishes frequently assume, when at rest, an inclined position, much as the young Garpike, and do not float horizontally as other bony Fishes do. See the figure in my former paper on the development of the tail in Plate II. Vol. XIII. Proc. Amer. Acad. 1877–78.

Günther* has figured (on p. 471, Introduction to the Study of Fishes) a young Lophius measuring over 70^{mm} in length, in which there are three long anterior dorsal filaments. The older of the young stages I figure resemble somewhat Melanocetus. The general resemblance of the more advanced stages of Lophius (Plate XVII. figs. 3, 6, Plate XVIII. fig. 1) to the Ophididæ and Macrouridæ is very striking.

Somewhat similar to the egg ribbons of Lophius are the masses of eggs laid by Fierasfer described by Risso and Cavolini, and also well figured by Emery,† who has followed the development of the young and given excellent figures of different stages; see Emery, Plate I. fig. 2, Plate II. figs. 5–7. They assume also, as do the young of Lophius, a peculiar slanting attitude characteristic of certain stages of growth. It is most interesting that such distant types as Lophius and Fierasfer should in their embryonic stages show such close resemblances. Compare the figures of this paper and figs. 5 and 6 of Plate II. of Dr. Emery's Memoir. It is not extraordinary that these forms should have been described under the different generic names of Vexillifer, Helminthostoma, and Porobranchus. The temporary dorsal appendage which is so prominent in the young Fierasfer (Emery, Plate I. fig. 2) is developed much in the same way as the

* See also Ann. and Mag. of Nat. Hist. 1861, vii. (3), p. 190.

† Fauna u. Flora d. Golfes v. Neapel. II. Monographie. Fierasfer, v. Dr., Carlo Emery, 1880.

permanent dorsal appendages of Lophius, which are eventually changed to the appendages used for fishing by the adult. What part this temporary dorsal appendage plays in Fierasfer is not known, but Emery supposes it to have the same function as in Lophius.

Cottus grœnlandicus, *C. & V.*

(Plate III., Plate II. figs. 1, 2.)

The eggs of this species (Plate III. fig. 1) are found floating on the surface; they are readily recognized from the number of small oil globules (from 10–12) which the yolk contains. Other Cottoids lay their eggs in bunches attached to the bottom, or singly between stones in shallow water. The young immediately on hatching (Plate III. fig. 2) are characterized by the great width of the anterior part of the body, the breadth of the embryonic dorsal fin toward the head, and the great size of the fleshy pectorals. Viewed from above, when slightly older (Plate III. fig. 3), the pectorals are seen to project far beyond the general outline as thick fleshy flaps; their formation as a fold of the primitive lateral embryonic fold is well shown in the stages within the egg (Plate III. fig. 1*a* 1*c*); in the last stage (Plate III. fig. 1*c*) they appear to stand independently of the body upon the yolk mass. In the stages of Plate III. figs. 4, 5, the rapid increase in the size of the head and of the pectorals can be traced. In the stage of Plate III. fig. 4, the permanent pectoral fin rays are commencing to form, and in Plate III. fig. 5, what we may call the crossopterygian stage of the pectorals is very striking.

The development of the anterior part of the body goes on, as in Lumpus, much more rapidly than that of the posterior, and at a stage (Plate II. fig. 1) where the Cottoid characters of the head and pectorals are already very striking, the embryonic dorsal and anal folds are still united with the caudal fold, and the tail only shows, as yet, a rudimentary caudal fin and the beginning of the ventrals.

In the next stage (Plate II. fig. 2) the spiny processes of the operculum and head of the young Cottus are well developed, and the pectorals fins have all the appearance of that of older specimens; the ventrals are well advanced, the dorsals and anals are separated from the caudal fin, the permanent fin rays are quite prominent, and the anterior dorsal exists as a low fin.

The general coloring of this stage of the young Cottus is of a dirty yellowish brown, with patches of darker pigment cells and black spots along the base of the anal fin, of the pectorals, and of the upper part of the stomach and head. In the youngest stages (Plate III. figs. 2, 3) there are two large patches of yellowish brown along the dorsal embryonic fin, four along the ventral, and the outer edge of the pectorals is colored in the same manner. In the subsequent stages (Plate III. fig. 4, and Plate II. fig. 1) the young have the general coloring of the older stages. This seems characteristic of other Cottoids, as in a young *Hemitripterus acadianus* corresponding to Plate III. fig. 4; the brilliant red coloring so characteristic of the adult is the prevailing tint of the pigment spots of that early stage.

Cyclopterus lumpus, *Lin.*

(Plates IV. V.)

In the youngest stage of this species I have had occasion to examine (Plate IV. fig. 1), measuring 4^{mm}, the caudal fin was already partly separated from the dorsal and ventral embryonic fin. The spiny rays were also indistinctly indicated in those fins. The pectorals were large, the rays gradually diminishing in length towards their junction with the sucking disk (the modified ventrals on the abdominal side). The anterior dorsal is formed evidently, as in Lophius, at an early stage, and separates, as in that genus, the anterior and posterior parts of the embryonic dorsal fin. The younger stages of Lumpus (Plate IV. figs. 1–4) are noted for the great length of the urostyle. The head of the younger stages is remarkable for its great length and breadth (Plate IV. figs. 1–4). The great prominence of the pigment spots on the anterior part of the young fish, as far as the base of the dorsal and ventral embryonic fins, gives the young Lumpus a very striking appearance. It resembles somewhat the armored Fishes of the Old Red, and we are strongly reminded of the restorations of Coccosteus in such stages as those of Plate IV. figs. 1 and 3. With increasing age and size (Plate IV. figs. 3, 4) the young Lumpus is more uniformly covered by pigment cells, the posterior part of the body becomes less transparent, more fleshy, and it loses its ancient look, resembling more, at this stage (Plate IV. fig. 4), the young of Batrachus, which may, indeed, be said to be a permanent condition of this stage of Lumpus (with the exception of the absence of the sucking disk in Batrachus). The posterior dorsal and the ventral have become well separated from the caudal fin, which in Plate IV. fig. 4, has nearly completely lost its ganoid shape, having become almost symmetrical. The urostyle, however, is still marked by its great length. The permanent rays of the median fins are well advanced (Plate IV. fig. 4); the paired fins have not changed materially since the last stage (Plate IV. fig. 3). There is great diversity in the coloring of the young of Lumpus. In the youngest stages (Plate IV. figs. 1–3) the head, in a line drawn nearly vertically below the base of the anterior dorsal, is of a light chocolate brown, with a darker brown band extending from the nostrils above the eye to the base of the anterior dorsal. A light blue band extends from the rear of the eye to the top of the operculum, and in front of the eye to the nostrils. A blue spot of similar tint is found at the posterior base of the dorsal and at the base of the caudal extremity of the posterior dorsal. The rest of the body is straw colored. The young of stage represented in Plate IV. fig. 4, were usually of a bright olive green, darkest towards the dorsal side, with the same blue band extending towards the operculum from the rear of the orbit, with one or two round blue spots above the level of the pectorals along the lateral line. Other specimens were of a bluish neutral slate tint, uniformly spotted with darker pigment cells, with the same blue band between the eyes, above the nostrils, and behind the eyes. This was also the coloring of the oldest of the young specimens caught (Plate V. figs. 1, 3), resembling in general the bluish coloring of the adult, only of a darker tint.

The intermediate stages varied greatly in coloring; some were of a yellowish brown spotted with chocolate-colored patches, with light greenish bands behind the eyes, and five roundish spots of the same color along the lateral line, and a similar number of larger spots along the base of the posterior dorsal, extending, in some specimens, along the median dorsal line of the body to the colored band extending between the eyes. Other stages, with a similar arrangement of elliptical spots of a bluish tint along the dorsal and lateral lines, were of a reddish brown color with pigment patches of a darker greenish or of a brownish color, the abdominal region being of a lighter color.

In the stage of Plate V. figs. 1, 2, the anterior part of the body already assumes somewhat the angular outline characteristic of the adult, though these young stages are all more elongated than the adult, having also the head comparatively well separated from the posterior part of the body. The young in the stages of Plate V. figs. 1, 2, do not as yet show any traces of the prominent rows of spiny tubercles formed in the adult. These were developed to a slight extent in young Lumpus measuring 34^{mm} in length (Plate V. figs. 3, 4): a line commencing to form along the anterior slope of the anterior dorsal, a less prominent horizontal row on a level with the line of the orbits close to the eyes, a third lateral one along the body at the level of the upper extremity of the operculum. This, the most prominent of the rows, consisted of large, elliptical protuberances, through which spiny processes projected (Plate V. figs. 3 *a*, 3 *b*), and a last row of somewhat smaller tubercles along the median line of the abdomen behind the ventrals. The anterior dorsal fins of these young stages (Plate V. figs. 3, 4) resemble greatly such permanent anterior dorsals as exist in Chironectes, for instance.

In the older stages (Plate V. figs. 1–4) the anterior dorsal has become well separated from the posterior, the median fins are entirely isolated, with well-developed fin rays, and the caudal has become symmetrical. The pectorals are somewhat larger, but otherwise they and the ventral fin disks (Plate V. fig. 3 *c*) do not differ much from their condition in younger stages. The early development of the pectorals seems a marked characteristic of all embryos of osseous Fishes.

These young stages of Lumpus were all collected close to the shore; they were found living among the eel-grass at Nahant, near low-water mark. Günther has figured* the young of *Cyclopterus spinosus*. Of these stages, the youngest correspond to the oldest stage of *Cyclopterus lumpus* here figured, the oldest measuring over 45^{mm} in length.

GASTEROSTEUS ACULEATUS, *Lin.*

(Plate IX.)

The changes due to growth in Gasterosteus closely resemble those of Fundulus. The principal differences consist in the longer persistence of the embryonic tail lobe, which is still very prominent (Plate IX. fig. 1) at a stage when in Fundulus the tail has become nearly symmetrical. The notochord continues to extend into the tail as late as the stage of Plate IX. fig. 4. The chromatophores are in the shape of irregular spots during early stages; they become more and more dendritic as the young fish grow older (Plate IX. figs. 2, 3, 4). In the stage of fig. 4 they begin to assume the arrangement forming the vertical bands of the adult, and in the oldest stage here figured (Plate

* An Introduction to the Study of Fishes (1880), p. 485.

IX. fig. 5) the general pattern is similar to that of the adult. In subsequent stages the spiny processes of the operculum are developed as well as those of the large ray of the ventrals. The ventrals make their appearance at about the time of the disappearance of the yolk bag (Plate IX. fig. 3), somewhat later than the formation of the rudimentary anterior dorsal spine (Plate IX. fig. 2). The outline of the young fish becomes more compact with age, passing gradually through the changes represented in Plate IX. figs. 1–5, from an elongated slender fish to one with a comparatively broader and stouter body.

Pelagic Fish Eggs.

The number of species of marine Fishes of which the eggs are pelagic is probably quite large. Scarcely a summer passes without some new egg being brought to light by the surface-fishing carried on at Newport. The eggs of the majority of our species of Flounders, those of Ctenolabrus, of Tantoga, of several species of Cottus, I know, from my own observation, to float on the surface of the water. Häckel has called attention to the pelagic eggs of Lota or some Gadoid which he had observed as early as 1866. Sars has shown the same to be the case with the eggs of the Cod. Mr. Ryder has figured the eggs of the Spanish Mackerel (Bull. U. S. Fish Com., i. Pl.) Both he and E. van Beneden, who also has observed pelagic fish eggs (Quarterly Journal Mic. Soc. 1878), have called attention to the value of these pelagic fish eggs for embryonic investigations. Mr. Ryder has also made observations of the spawning of Zeus, and suggests that many of the marine Fishes are nocturnal spawners. That this is the case with many of the Fishes I have named above seems probable from the state of segmentation in which they are found to be on the morning following the day on which they were collected. The pelagic eggs collected during the day were invariably well advanced, and the experiments for artificial fecundation which I have made with Ctenolabrus and Tautoga to obtain the very earliest stages of the development of the egg were invariably made late in the afternoon, towards dusk. I have long known the eggs of Lophius to occur floating on the surface as a gigantic mucous band, and they have also been subsequently collected by the U. S. Fish Commission. The eggs of Fierasfer are also pelagic; see Emery's monograph. I have myself also collected the eggs of the Spanish mackerel on the surface, and have observed a couple of stages of the young considerably more advanced than those figured by Mr. Ryder. The youngest of the stages I have observed correspond very closely with the stage figured by Mr. Ryder on Plate IV. fig. 16, Bull. U. S. Fish Com. It was remarkable, however, for having a lateral anal opening close to the notochord, the anal embryonic fin extending unbroken beneath it from the operculum to the extremity of the tail. The older stages are very readily distinguished from other fish embryos by the large pigment spots which are formed one above the other, and by three large patches dividing the posterior part of the body into nearly equal parts, from the extremity of the anal opening to the tail.

Ctenolabrus cœruleus, *Dek.*

(Plates XIII. XIV. XV.)

The egg of Ctenolabrus floats on the surface immediately after being laid, and the eggs in all stages of development are fished up with the hand-net from June to the last part of August. The greater number of the eggs appear to be laid in July. The segmentation of the egg is rapid; in less than twelve hours after fecundation there are sixteen segmental spheres. In fifty hours the embryonic cap is well formed; in fifty-two hours the eyes are blocked out; and the young fish is hatched in from four and a half to five days in the stage of Plate XIII. fig. 1, measuring about 2^{mm} in length. The yolk bag is large, elliptical, and it (as well as the embryonic fin fold) is free from chromatic cells, which cover only the dorsal part of the body, and stop a little way short of the extremity of the notochord. On the second day after hatching (Plate XIII. fig. 2) the young Ctenolabrus is about 3^{mm} in length, the body is much more elongated, the head especially has lengthened, the distance between the eyes and the otoliths is nearly double, the rudimentary pectorals are better marked, and the distance of the vent from the yolk has greatly increased. The black chromatic cells have also increased in number, and are proportionally smaller than in the preceding stages. On the third day after hatching (Plate XIII. fig. 3) the young Fish presents a totally different appearance: the chromatophores characteristic of the early stages within the egg immediately after hatching have disappeared, there are left but a few large cells in the anterior part of the head, behind the pectorals along the dorsal, while there are in this and the subsequent stage (Plate XIII. fig. 4) large patches of pigment cells, and large chromatophores at the base of the anterior termination of the notochord below the level of the eyes. We find also along the body a large patch at the posterior extremity of the stomach, a second at the end of the intestine near the vent, with a smaller patch between this and the anterior one, and a third prominent patch extending across the body half way between the vent and extremity of tail, with a couple of smaller spots in front and one behind this patch. In the stage of Plate XIII. fig. 3, the opening of the mouth is still inferior, the pectorals have greatly increased in size since the preceding stage, the body has much lengthened, the vent is placed about half way between the anterior and posterior extremity, and the embryonic fin folds are comparatively much narrower. In a stage but slightly older (Plate XIII. fig. 4) the chromatophores are larger and more prominent, the pectorals have increased in size, the head has increased in length, the mouth is more anterior, the yolk bag has become much reduced, and the heart and alimentary canal have greatly increased in size. In the next stage (Plate XIII. fig. 5), the fourth day after hatching, the young Fish measures about 4^{mm} in length, and has greatly changed from the preceding day. The opening of the mouth is anterior, the branchial rays have been formed, the heart is divided into chambers, the stomach proper has greatly increased in size, and the intestine is better specialised than in the younger stages. The muscular bands appear well defined above and below the notochord, embryonic caudal rays are quite distinct, the permanent pectoral rays are blocked out, and the pigment cells are reduced to the three large patches described in the previous stage and a few smaller cells round the eyes and on the head. A small but prominent pigment spot has made its appearance near the end of the notochord on the lower side of the body. The stages intermediate between Plate XIII. fig. 1, and Plate XIV. fig. 1, were not traced. In Plate XIV. fig. 1, the caudal is well developed, showing but a slight trace of its ganoid lobe. The head is much larger, the body comparatively stouter, the mouth anterior, the branchiæ well developed, and important changes have taken place in the size of the stomach. In the next stage (Plate XIV. fig. 2), measuring 6^{mm} in length, the snout has become more pointed, and the body is quite broad and comparatively much flattened.

The spinal apophyses, of which a few could be seen in the preceding stage, are large and well developed, the dorsal and ventral muscular bands have become most prominent, there is a trace of the origin of the ventrals, the anal and dorsals are separated from the caudal embryonic lobe by a deep narrow slit, and in both these fins, as well as the caudal, the permanent rays have begun to be formed, being most advanced in the caudal fins. There are two gigantic black chromatophores extending over the dorsal part of the stomach, three prominent chromatophores of the same color in the posterior flanks of the body immediately in the line of separation of the dorsal and anal from the caudal lobe, and the remnant of a small black pigment patch at the base of the caudal rays. On the top of the cerebrum there is a patch of black pigment, and also on the anterior part of the dorsal line near the base of the brain. The general color of the young fish at this stage is yellowish, with brilliant yellow patches surrounding the dark patches of black chromatophores; the eye is of a dull blue color, with a black band above the pupil. In the next stage (Plate XIV. fig. 3), measuring 6.5^{mm} in length, the caudal fin has lost its ganoid lobe and has become symmetrical; the cleft separating the dorsal and anal from the caudal lobe has completely isolated them from the caudal; the snout has lengthened somewhat, the pectorals and ventrals have become larger. The principal difference in the appearance of these two stages consists in the great development of closely packed chromatophores, which cover uniformly the whole body and the posterior part of the head. The fins alone are as yet free from them; but at the base of the dorsal and anal there is a prominent continuous line of black pigment cells, and a few small inconspicuous chromatophores at the base of the caudal rays. The next stage (Plate XIV. fig. 4), but slightly older than Plate XIV. fig. 3, measuring 7^{mm} in length, differs from it mainly in the absence of the coating of chromatophores. There are, as appears from this stage (Plate XIV. fig. 4), from that of Plate XIV. fig. 3, and from the subsequent stage figured, three sets of coloring characterized by the extremes here figured. One as in the stage of Plate XIV. fig. 3, with densely packed dendritic chromatophores; the other, fig. 4, with only a few prominent patches of large chromatophores, and the intermediate stage (Plate XIV. fig. 5), measuring 11^{mm} in length, in which we have the large prominent patches (Plate XIV. fig. 5), with the band of continuous pigment cells along the base of the dorsal and anal, and the body uniformly covered with comparatively small pigment spots. This will probably account for the great differences already noticed in the youngest stages (Plate XIII. figs. 4, 5, 6, and Plate XIII. 1, 2, 3) in the presence or absence and distribution of the dendritic chromatophores. We might naturally expect such a difference from the innumerable variations in coloring noticed in the adult Ctenolabrus. During a single season at Nahant, the late Professor Agassiz had no less than sixty colored sketches made of specimens of this species, measuring from three to four inches in length, illustrating differences in the coloring or markings. In younger stages, when the young Ctenolabrus measures not more than 15^{mm} in length, I have found fully as great a variety in the types of coloration as among the adult; the principal types of coloring varying from a perfectly uniform light green tint to a mottled and banded pattern, which recalls far more Julis than the usual pattern of design and coloring found in our Ctenolabrus. The next stage figured (Plate XV. fig. 1) is but slightly more advanced than Plate XIV. fig. 5; it belongs to the light-colored type. The principal differences to be noticed are the nearly complete disappearance of the caudal embryonic fold and the formation of a rudimentary anterior spiny part of the dorsal. In a young Ctenolabrus (Plate XV. fig. 2) measuring 11^{mm} in length, this anterior part of the dorsal is somewhat more developed; the urostyle is much smaller. This specimen belonged to a type of coloring of which the adult has patches of darker color along the dorsal and ventral lines, these patches also extending over the anal and dorsal fins. The darker chromatophores are black, those of the dorsal fin and along the dorsal are of a light-brown color, and the whole upper part of the body and head is colored a brilliant yellow. In a young Ctenolabrus measuring 15^{mm} in length the anterior part of the dorsal has greatly increased in height, the posterior ends of the dorsal and anal have become rounded, and there is no trace of the rudimentary caudal embryonic fin. Young specimens of the same length were either uniformly covered by closely packed brownish or black chromatophores on a reddish-brown or greenish background, or else the darker chromatophores were arranged in bands, slanting from the median line towards the tail, with irregular patches at the base of the dorsal fin and along the dorsal side, or else they were of the pattern figured here (Plate XV. fig. 3) upon a light yellowish background.

In a somewhat more advanced stage (Plate XV. fig. 4) of about the same length as Plate XV. fig. 3, the body and head of the young Ctenolabrus have become quite compact, the fins resemble in outline those of the adult, and the young Ctenolabrus has practically assumed the principal characteristic features of the older and larger fish. Fishes in the stages of Plate XV. figs. 2–4, are still pelagic, though many of them can be caught in the eel-grass or kelp along with the older fishes.

The young Ctenolabrus at a very early age assume the peculiar slanting of the body which the older fish take specially when feeding or when coming up to examine any object.

Motella argentea, *Rhein.*

(Plate VII. Plate VIII. figs. 1–3.)

The youngest specimen of this species I have seen (Plate VII. fig. 1) measured 4^{mm} in length. It was remarkable for the comparatively strong coloring for so young a stage. The head dorsal and ventral muscular lines, as well as the sides of the stomach, are of a dark dirty yellow. The pectorals are large and transparent, but the ventrals, already well developed, are of a dark maroon color. The lower part of the eye is light blue, the pupil of a dark crimson. About half way between the tail and pectorals there are two large pigment cells, one in the dorsal, the other in the ventral side of the notochord. A smaller cell indicates the position where the embryonic caudal fin rays are forming.

There are three pigment cells on the brain, the largest in front, two smaller ones at the extremity of the snout, one on the lower and one on the upper jaw, with a still smaller cell at the base of the operculum. Four to five larger cells form a black edge to the upper side of the stomach. In a somewhat older stage (Plate VII. fig. 2) the principal differences consist in the greater size of the pectorals, the larger ventrals, the increase in size of the chromatophores on the head and stomach, and the greater elongation of the snout. Seen from above (Plate VII. fig. 3) the ventrals appear like wings proportionally as large as the pectorals of the young Flying-Fish. In a young fish measuring 7^{mm} in length (Plate VII. fig. 4) the pectorals have increased but little in size since the preceding stage. The ventrals are nearly one third the length of the fish. The head, quite rounded above, is proportionally larger, and the body much wider and less elongate than in the younger stages (Plate VII. figs. 1–3).

The chromatophores are more numerous in the upper part of the head and on the upper part of the stomach, while the single cell of the dorsal region half way to the tail has increased to a large patch of chromatophores, and forms in this stage the largest accumulation of pigment cells. The permanent rays of the caudal fin are well advanced, and at the base of each is placed a minute pigment spot. The permanent rays of the dorsal and anal are also commencing to form, but they are far less advanced than those of the caudal. The embryonic fin rays are still to be traced in that part of the fin fold which unites the caudal lobe with the dorsal and anal. The coloring of this stage is greener than in the preceding stages; the greenish tint is especially marked on the upper part of the head and near the dorsal patch of chromatophores. The ventrals are somewhat darker colored than the younger stages. In all the stages thus far figured the young fish swims mainly by means of the powerful stroke of the ventrals, which they spread like wings laterally to their fullest extent at right angles to the body. In a somewhat more advanced stage (Plate VII. fig. 5), measuring 12^{mm} in length, the body has increased greatly in length, the pectorals are longer, the ventrals are less than one-fourth the length of the body; the caudal has become terminal and rounded, and quite well separated from the dorsal and anal; the permanent fin rays are well developed in the three median fins; the head has become lengthened, and the pigment spots of the upper part of the head and anterior part of the body are smaller and more numerous than in the preceding stages.

The chromatophores along the dorsal line and base of the dorsal and anal are now arranged in longitudinal lines. The coloring of the body behind the anterior base of the dorsal, as well as the head, has assumed a yellowish-green tint slightly bluish towards the ventral side.

In a subsequent stage (Plate VII. fig. 6), but slightly older, the greenish color of the dorsal part of the fish has become more marked, and there exists a principal lateral line of black chromatophores extending from the operculum nearly to the posterior extremity of the dorsal; the extremity of the body near the caudal is still quite transparent, of a yellowish tint, showing the ganoid termination of the notochord. The ventrals in this stage are proportionally longer again than in Plate VII. fig. 5, being somewhat more than one quarter the length of the fish. Viewed from above, the young fish is often seen with ventrals spread at right angles, as in Plate VIII. fig. 1 *a*, or flapping them violently up and down when excited, or as in Plate VIII. fig. 1, when swimming rapidly. In a somewhat older stage (Plate VIII. fig. 2) the dorsal and anal fins are well separated from the caudal; the anterior dorsal has commenced to form; the ventrals have lost somewhat their wing-like character, they are usually carried folded, and appear more like long fin rays; the head has lengthened, is more rounded, sloping anteriorly; the pectorals are elongated, and the greenish blue color of the body is limited to the dorsal regions, the sides being silvery; a colored belt, slightly greenish, extends along the base of the anal. In the oldest pelagic specimen of young Motella (Plate VIII. fig. 3) the barbel of the lower jaw is well formed, the anterior dorsal is higher than the posterior dorsal, the ventrals are long fin rays equalling in length one third of the length of the young fish, the greenish blue color of the dorsal region is more intense than in the younger stages, and extends in slightly lighter-colored diagonal bands across the flanks; the posterior part of the dorsal, of the anal, and the base of the caudal are marked with small black pigment spots at the base of the permanent fin rays. In this stage and in the one immediately preceding (Plate VIII. fig. 2) the young fish make but little use of their ventrals while swimming. The extremity of the caudal is cut quite sharply at right angles to the longitudinal line, with slightly rounded corners. At this stage the resemblance to Bregmaceros is striking.*

GADUS MORRHUA, *Lin.*

(Plate VIII. figs. 4, 5.)

The only other Gadoid of which I have found the young by fishing on the surface is probably our common Cod; when only 28^{mm} in length it has in this early stage (Plate VIII. fig. 5) assumed all the characteristic features of the genus. The only other young stage I have seen is a young Cod measuring 20^{mm} in length (Plate VIII. fig. 4), which differed from fig. 2 in not having a barbel, and in having the median fins still connected, although the three dorsal and two anals were quite distinct. The pigment cells were not arranged to form any definite pattern, but covered uniformly the dorsal region. The breaking up of the continuous embryonic dorsal and anal into separate fins is admirably seen in the stage represented in Plate VIII. fig. 4.

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* Emery in his monograph of Fierasfer has also figured the pectorals of the young Merlucius and Motella. There is still some uncertainty with regard to the genus to which the specimens I have here referred to Motella belong; they may prove to be one of the species of Onus described by Collet.

Fundulus nigrofasciatus, *C. & V.*

(Plates XIX. XX.)

Sundevall has already given the principal changes of form which Cyprinus undergoes while passing from its leptocardial stage to that of the adult. I have traced the principal changes of growth in one of our species of Fundulus, and find they agree fairly with the stages figured by Sundevall. That in the youngest stages the crossopterygian nature of the pectorals is owing to their large size is perhaps as striking as in any other embryo of osseous fish known to me. (See Plate XIX. figs. 5, 6, in which are given a view of the pectorals, fig. 6, from above; partly in profile, fig. 5; and a side view of a large pectoral (fig. 4), in which the fleshy base and the embryonic rays of the fin are best developed just previous to the appearance of the first trace of the permanent fin rays.) The gradual change of the pigment cells from a linear arrangement to the characteristic pattern of the adult is readily traced in the oldest specimens figured on Plate XX.

Osmerus mordax, *Gill.*

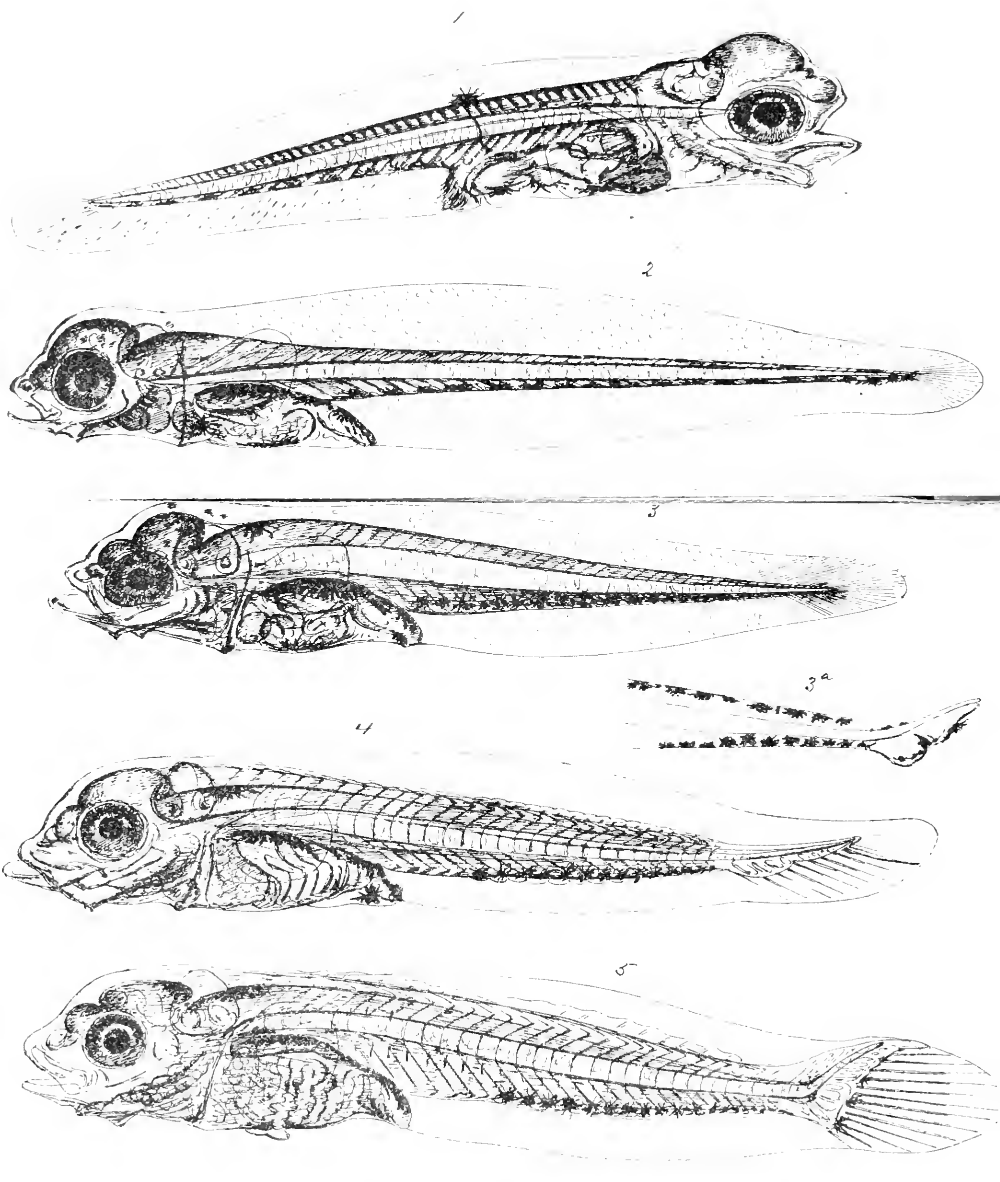
(Plate XII.)

The egg is pelagic, quite transparent; the young on hatching are about 5^{mm} in length (Plate XII. figs. 1, 2), with a comparatively small yolk bag, very rudimentary head, huge eyes, the vent placed at about three quarters of the length of the body near the posterior extremity, pectorals quite rudimentary. There are no pigment cells in this stage in any of the young I have collected. In the next stage figured (Plate XII. fig. 3) the young fish has greatly changed, the head is quite elongate, branchiæ are present, the lower jaw projecting beyond the upper one, pectorals large, eye brilliant emerald green, the yolk bag has completely disappeared, the caudal embryonic fin rays are very marked; we can also see the first trace of the separation between the caudal, anal, and dorsal. A prominent row of large pigment cells extends along the base of the anterior anal embryonic fin fold, with a smaller line extending along the upper side of the intestines, a few small pigment cells at the extremity of the notochord, along the base of the posterior anal and of the operculum, with two or three pigment cells along the dorsal line about half way from the head to the tail.

In the next stage figured the young Osmerus is considerably older, measuring already 22^{mm} in length; the caudal is completely separated from the dorsal and anal, in both of which the permanent fin rays already exist; there are rudimentary ventrals present in this stage. The general coloring of the body is a light dirty yellow, with patches of more brilliant yellow along the lateral line and base of the head. There is one line of greyish pigment spots along the dorsal side of the notochord, a very prominent line of large pigment cells running somewhat below the notochord, extending from the base of the pectorals to the vent, with four or five large pigment cells along the base of the anal and the ventral line towards the base of the caudal. Small pigment spots extend along the base of the caudal fin rays, with three or four larger spots at the base of the caudal fin. The oldest stage I have found (Plate XII. fig. 5) was not larger than Plate XII. fig. 4, but the caudal, anal, and dorsal were in a more advanced condition, the permanent fin rays better marked, the head less elongate, the body behind the ventrals comparatively broader. The great resemblance of this stage of Osmerus to Scomberesox and Belone in the general arrangement of the median fins and the great elongation of the body is striking. Mr. H. J. Rice has, in the Report of the Commissioner of Fisheries of Maryland for 1877 (Plates III. V.), given excellent figures of several young stages of the Smelt. The figures here given complement the stages already known, and with those of Mr. Rice give a fair sketch of the principal changes of the Smelt due to growth. The resemblance of the development of Osmerus to that of the Herring as given by Sundevall is very striking. Sundevall figures young fishes, which he calls embryo Herring, from 8 to 38^{mm} in length, but he does not state whether they were actually raised from eggs of known origin. Before the publication of Mr. Rice's paper I had already supposed the young fishes figured on Plate XII. to be the young of some Clupeoid, but the figures given by him seem to leave no doubt that the young I figure on Plate XII. belong to the Smelt.

Agassiz Young Osseous Fishes

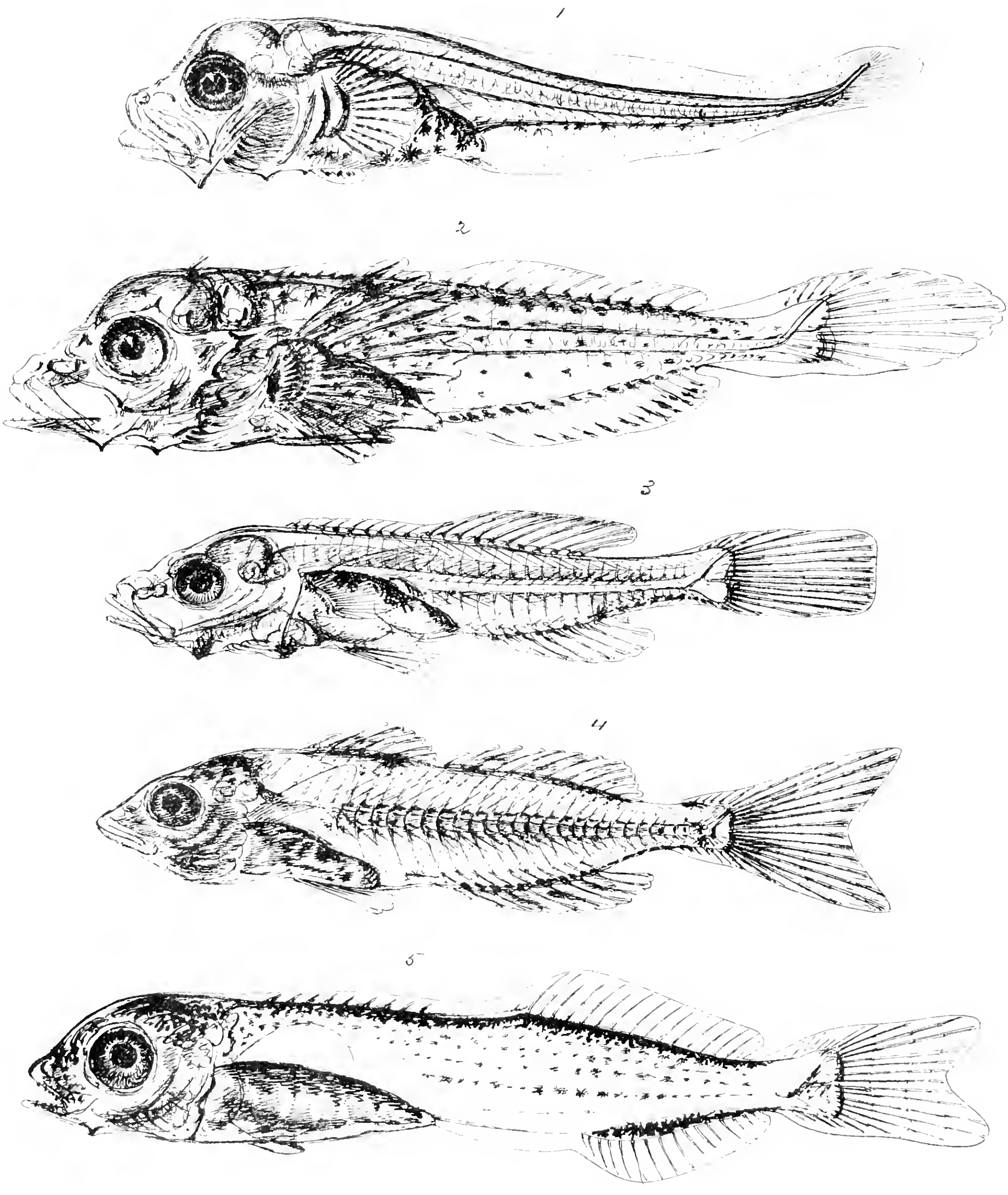
Pl. I



A. Ag. del.

Agassiz' Young Osseous Fishes

Pl. II



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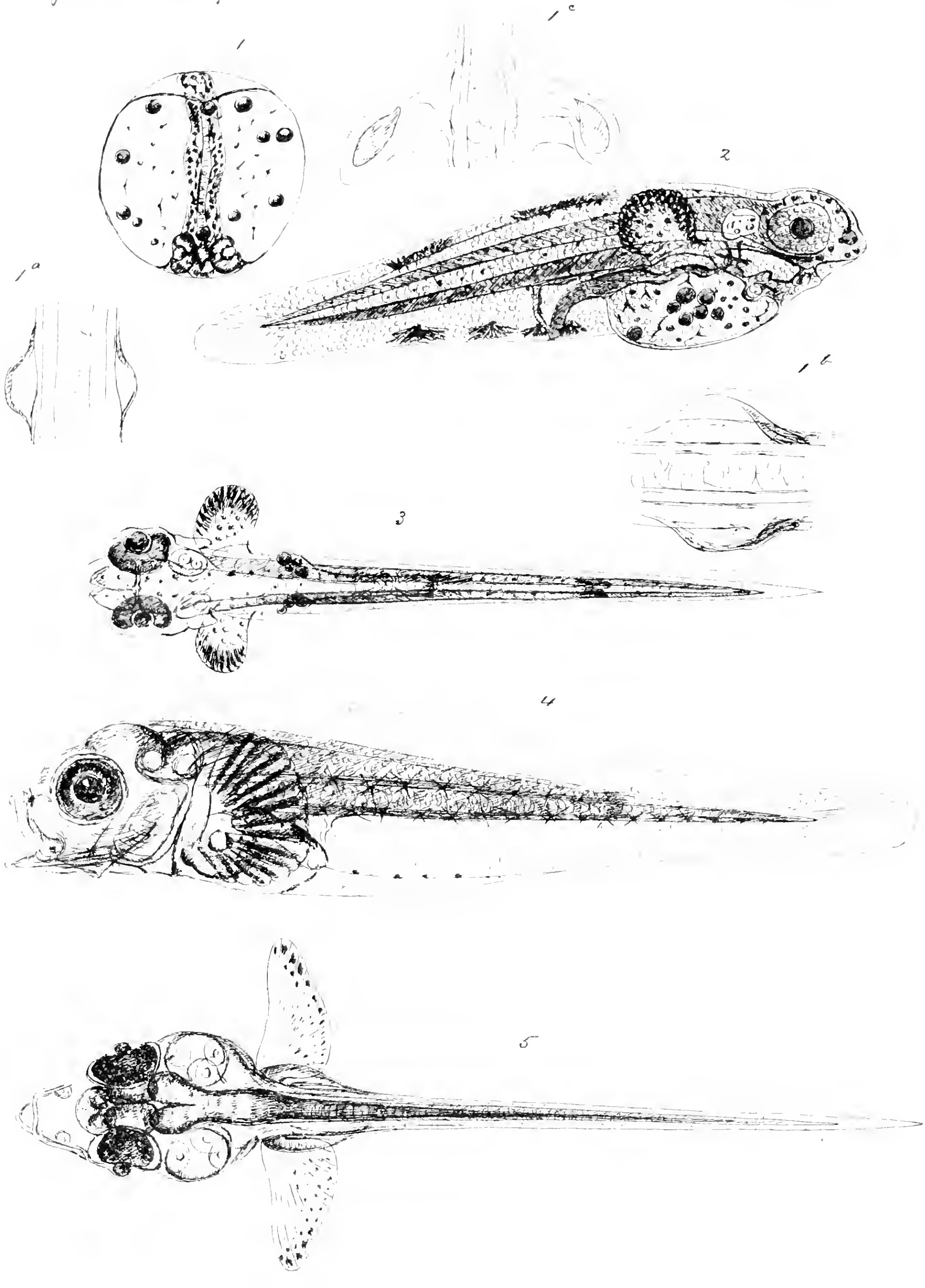
Agassiz' Young Osseous Fishes.

Pl. III.



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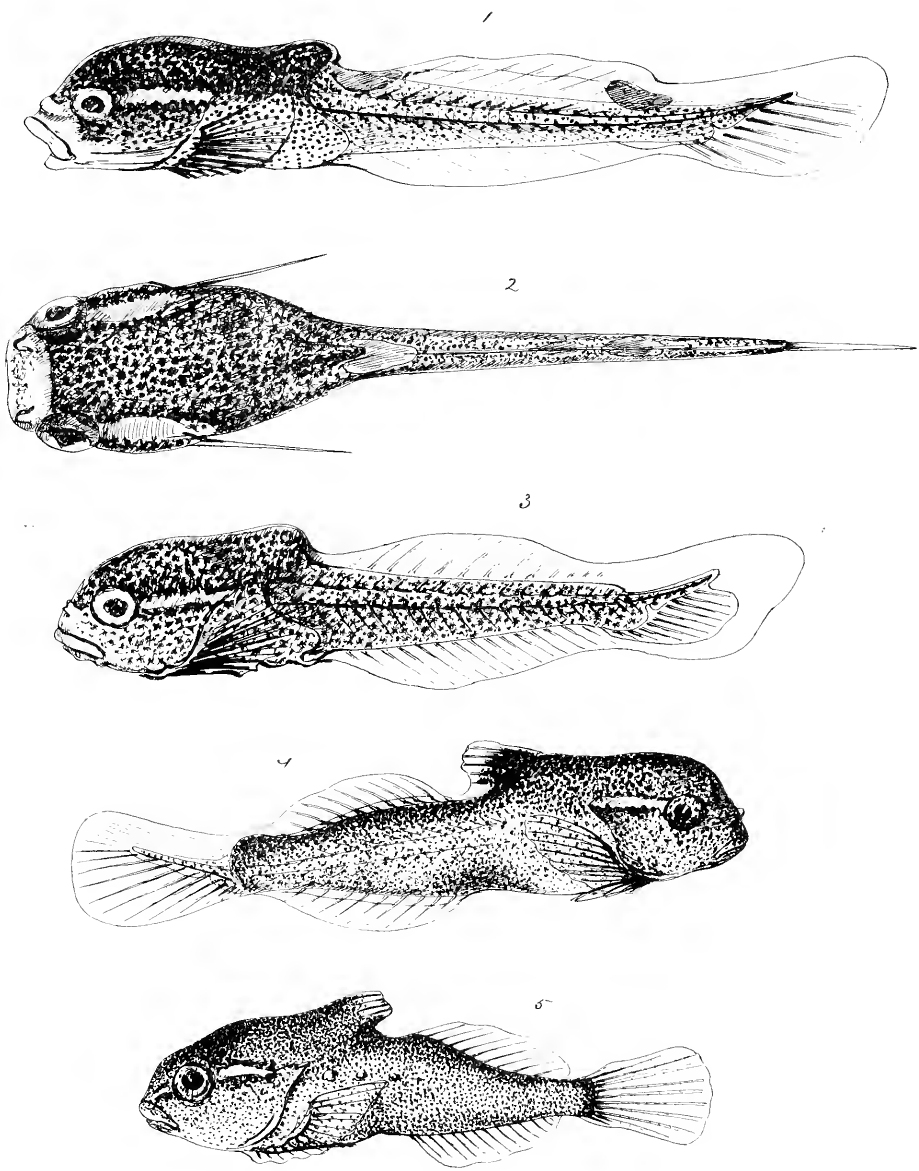
Agassiz' Young osseous Fishes

Pl. IV



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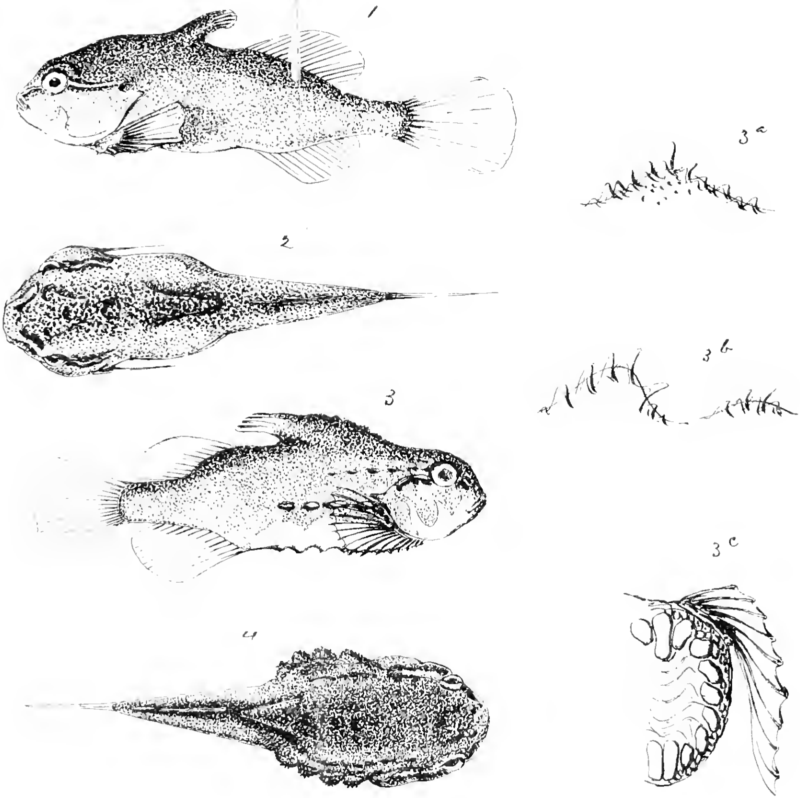
Agassiz' Young Osseous Fishes

Pl. V



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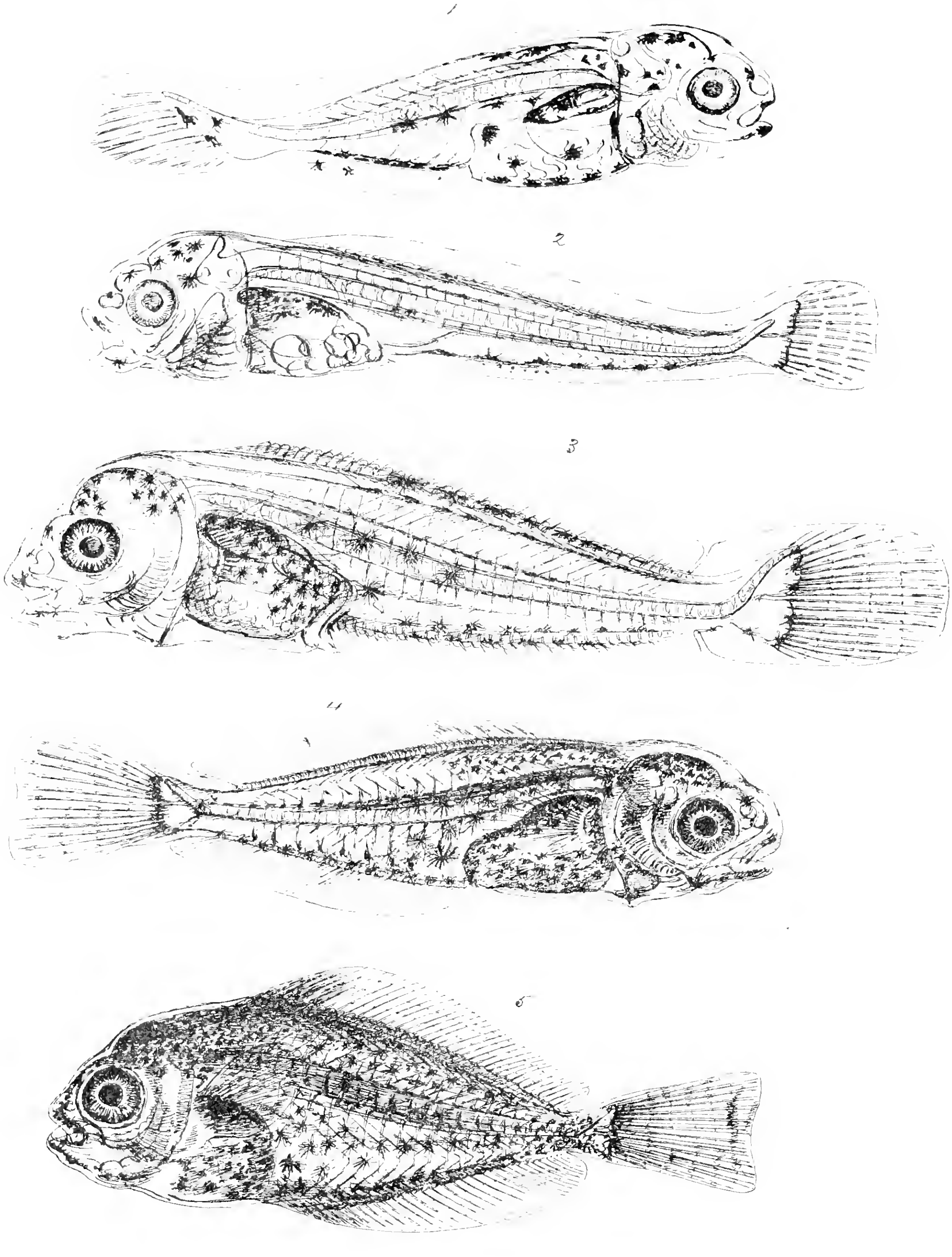
Agassiz' Young Osseous Fishes

Pl. VI



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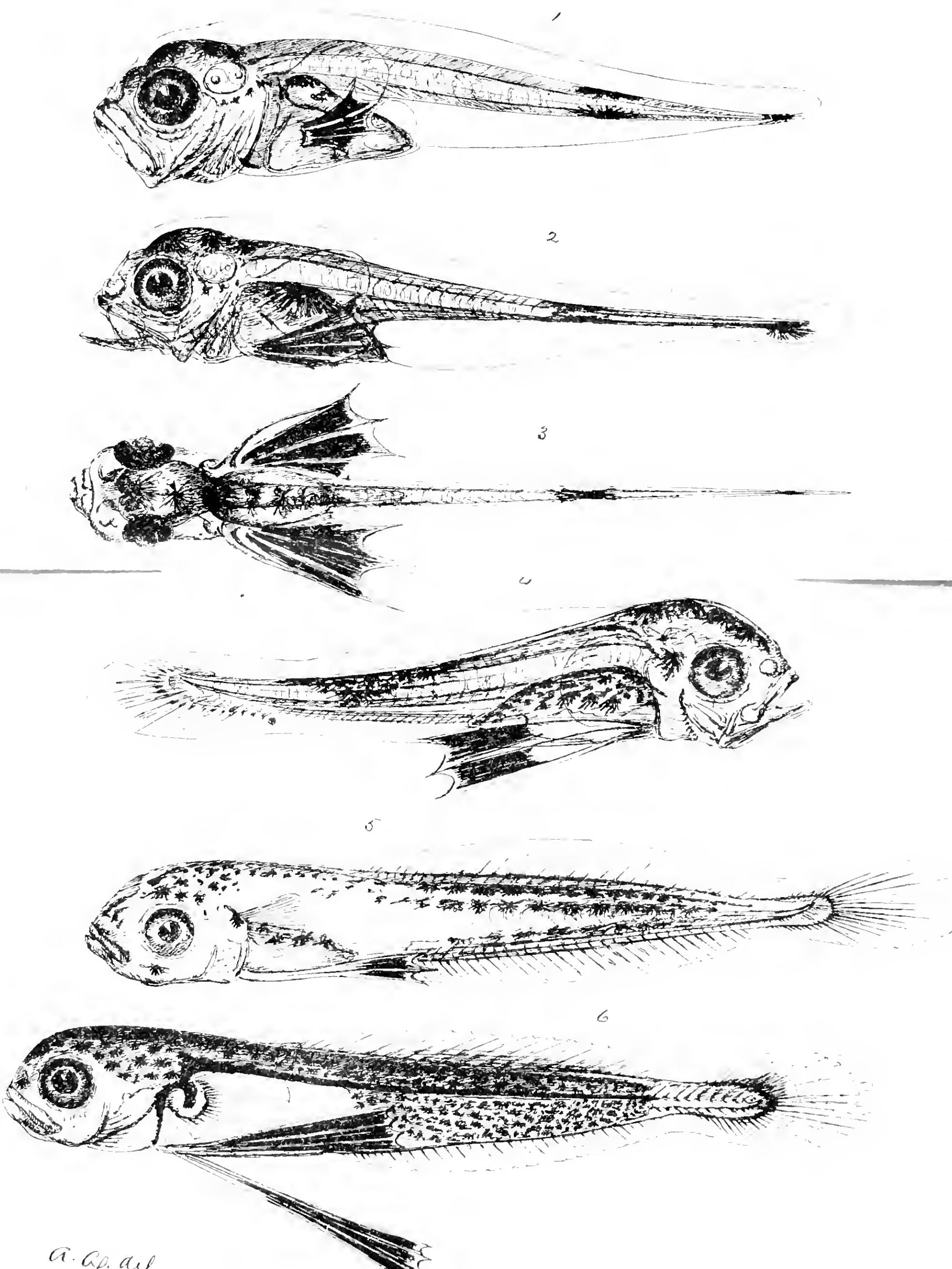
Agassiz Young Osseous Fishes

Pl. VII



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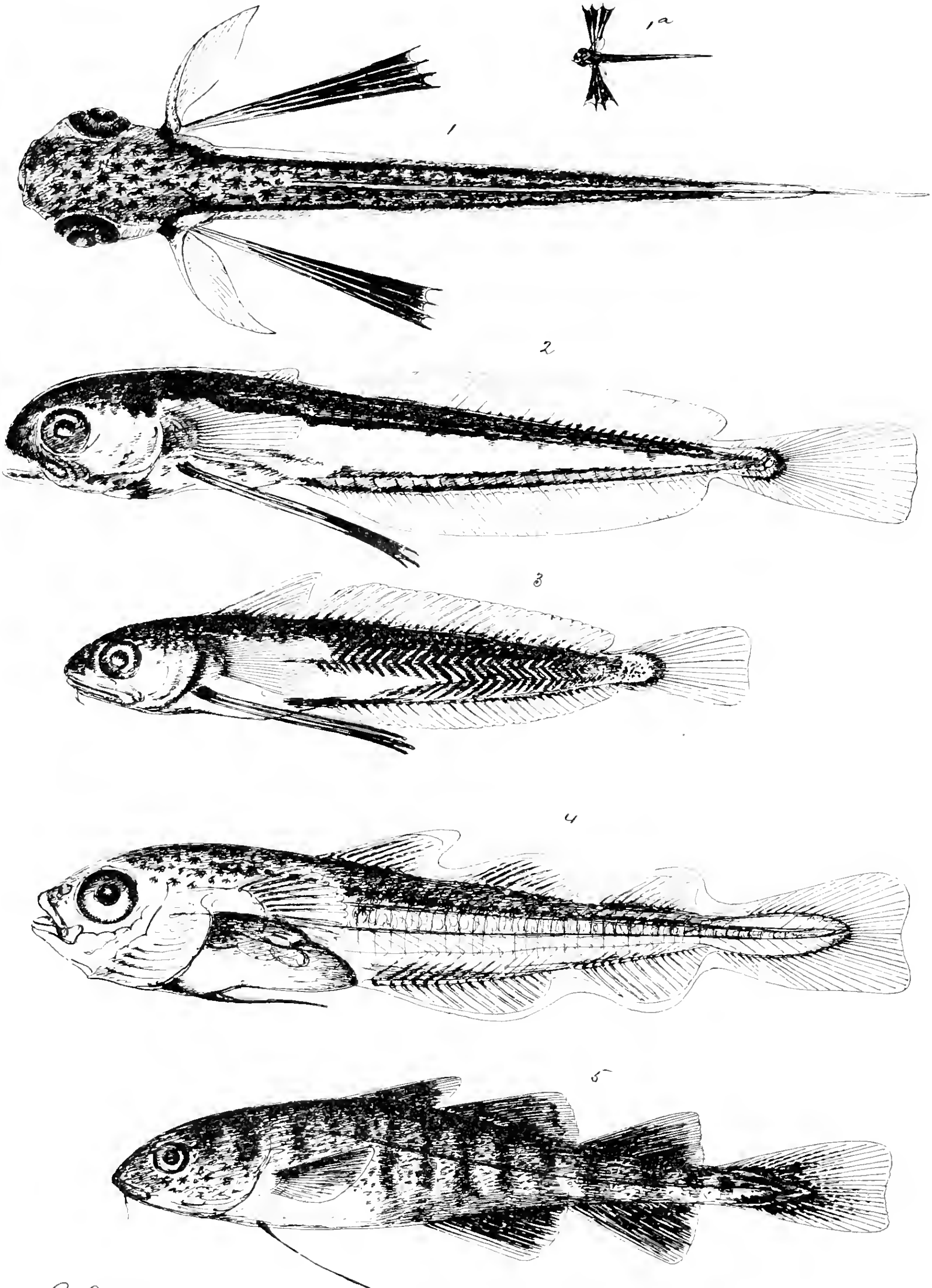
Agassiz' Young Osseous Fishes

Pl. VIII.



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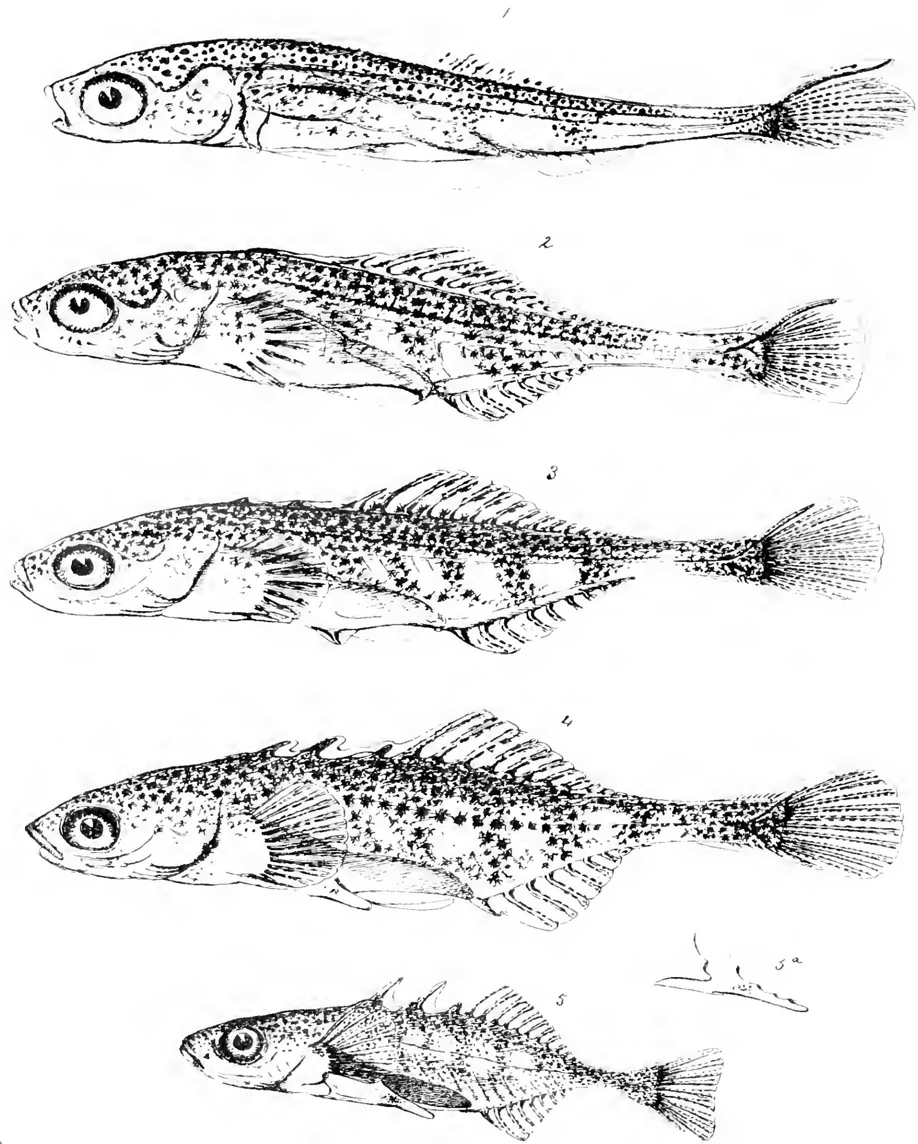
Agassiz Young Osseous Fishes

Pl. IX



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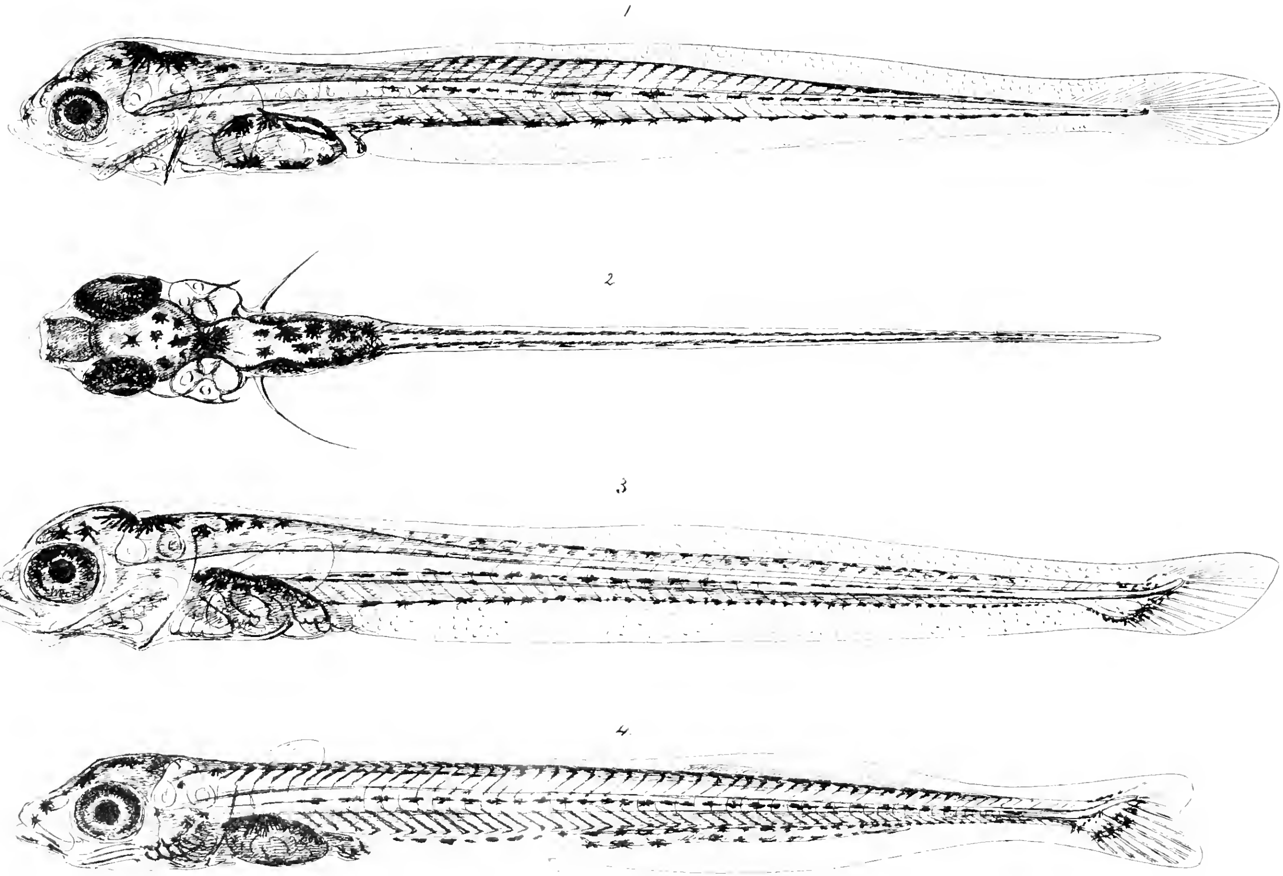
Agassiz' Young Osseous Fishes

Pl. X.



A. Ag. del

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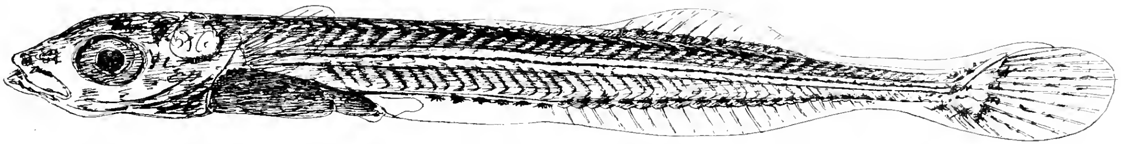

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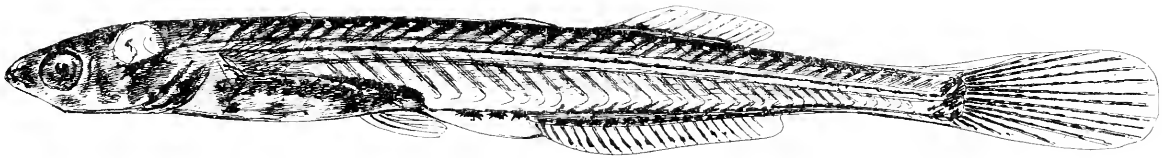

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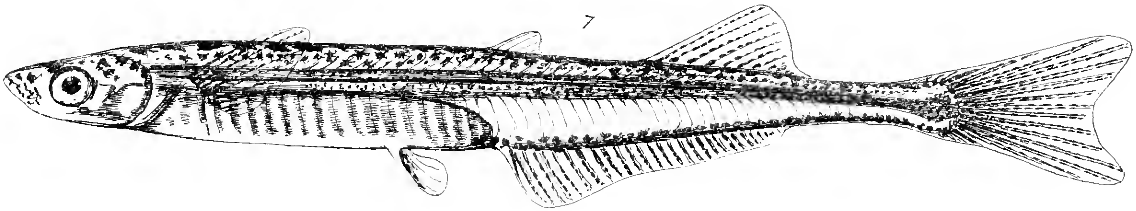

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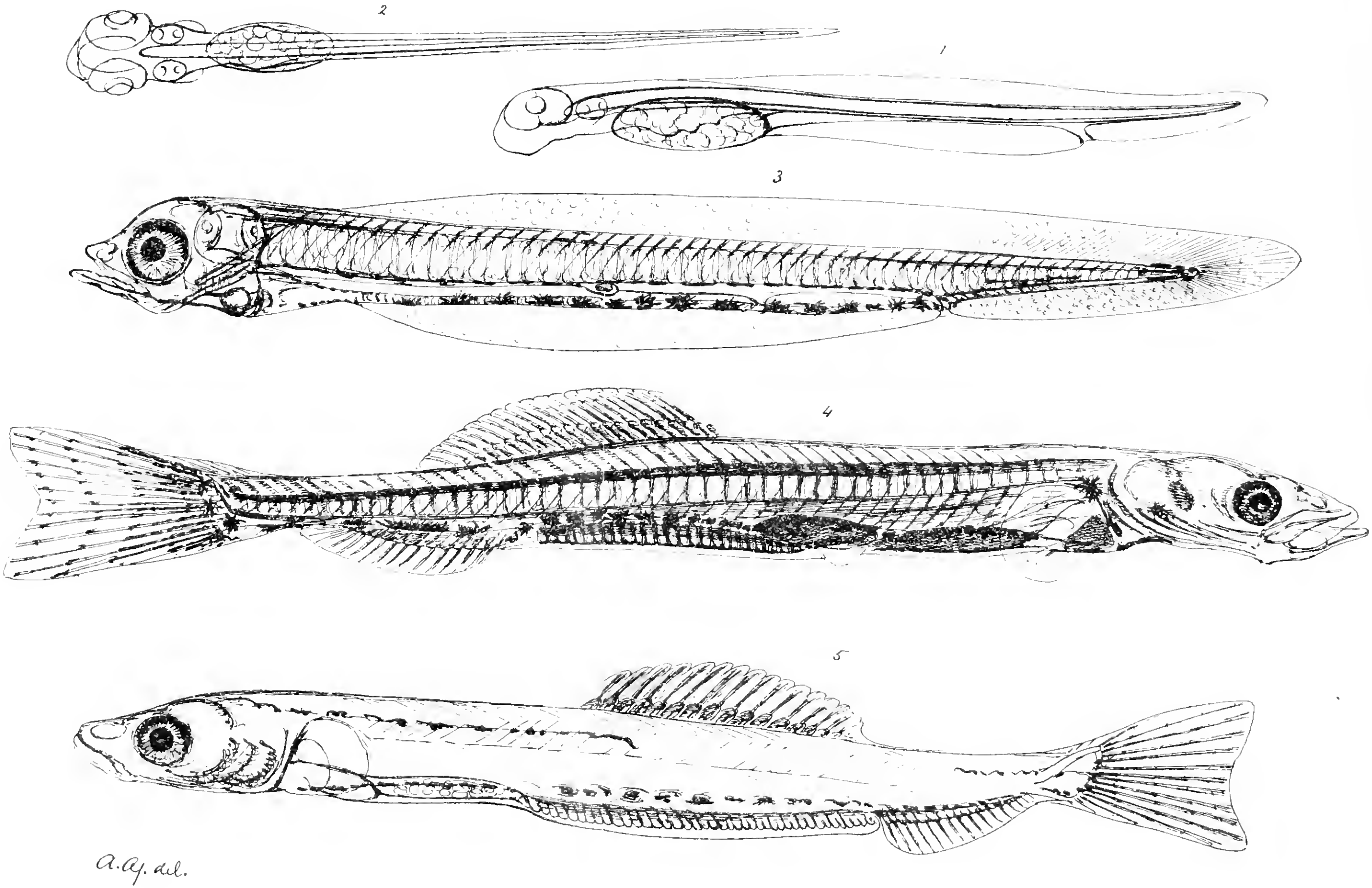
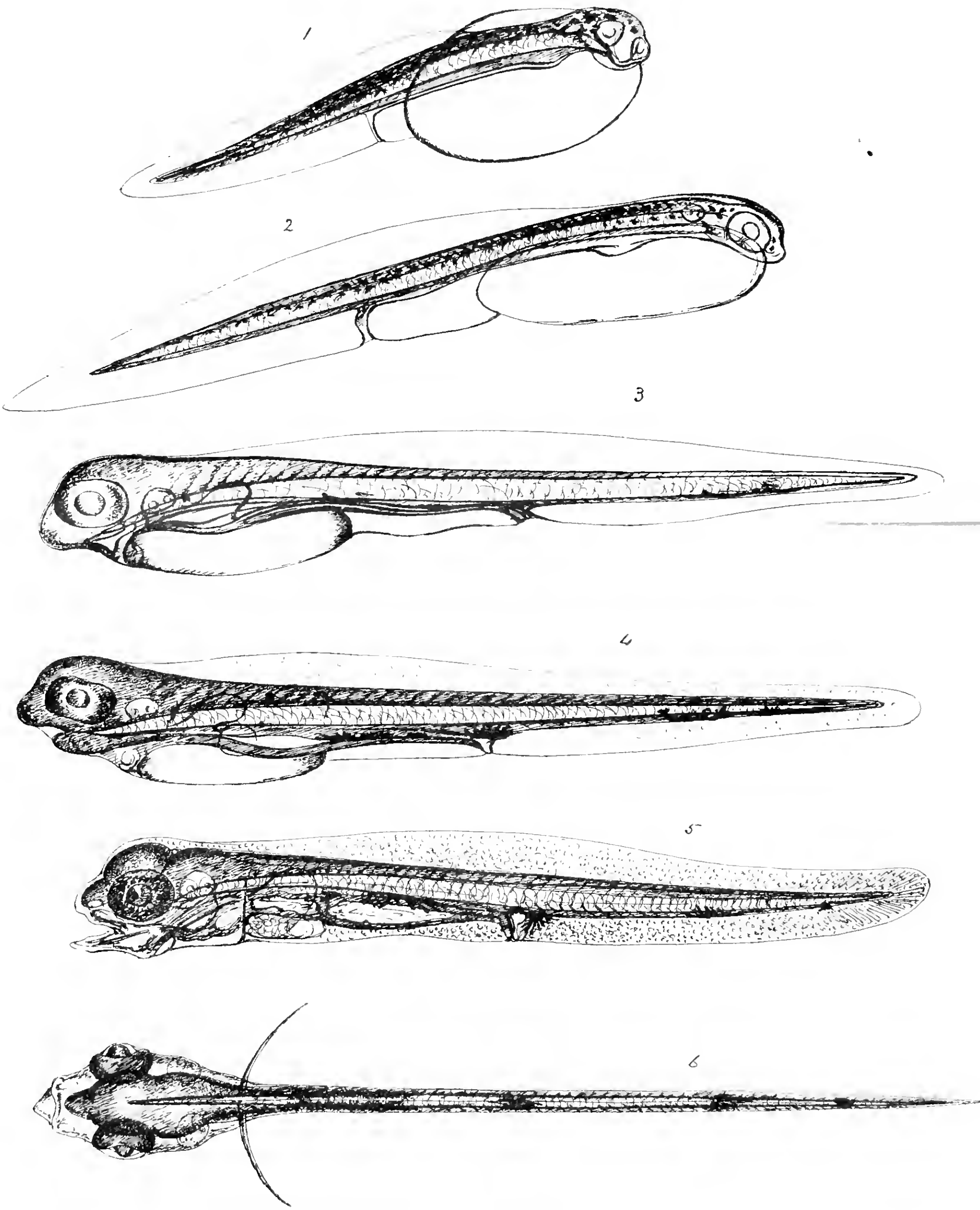
Agassiz' Young Osseous Fishes

Pl. XII



Agassiz Young Osseous Fishes

Pl. XIII



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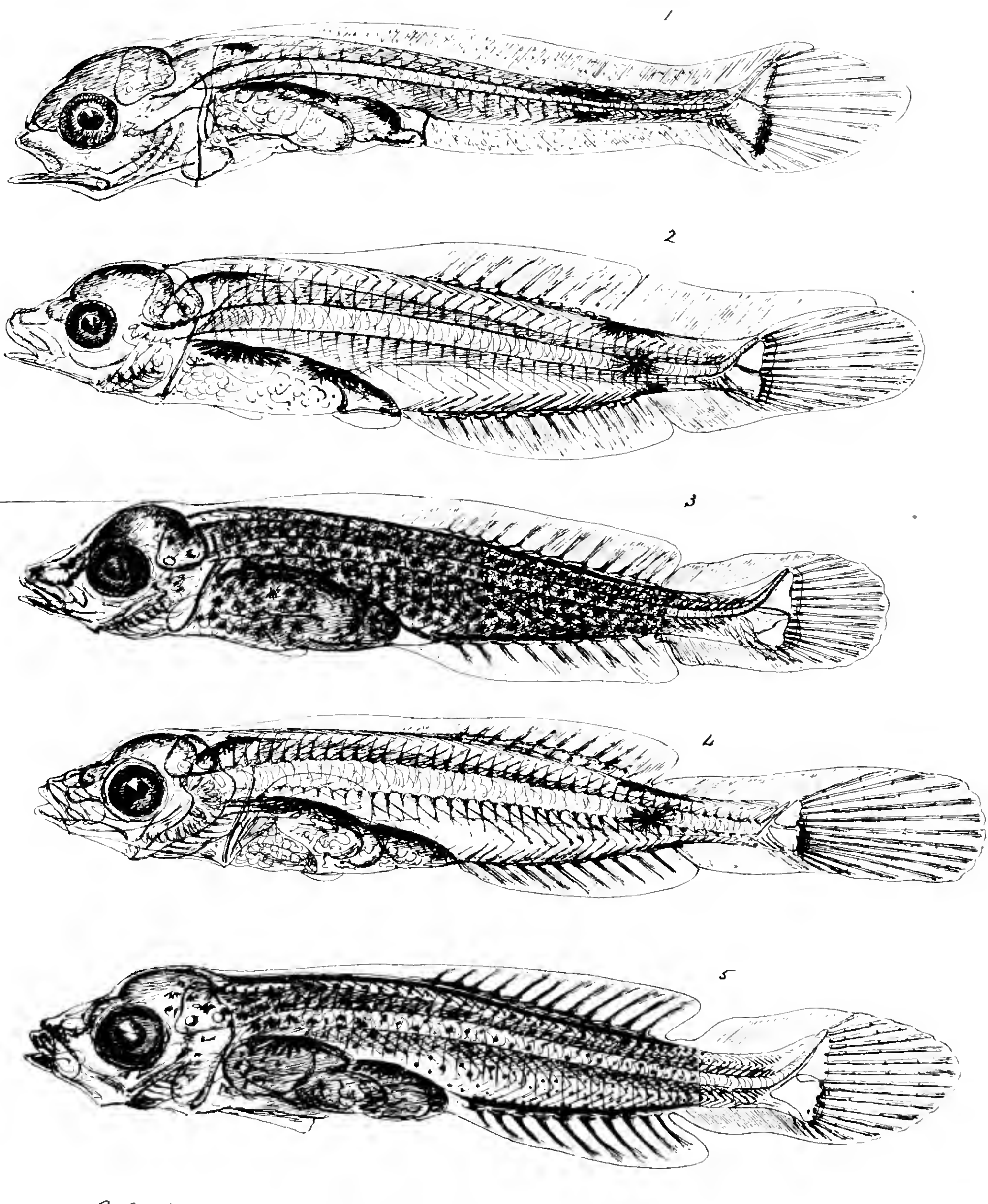
Agassiz Young Osseous Fishes

Pl XIV



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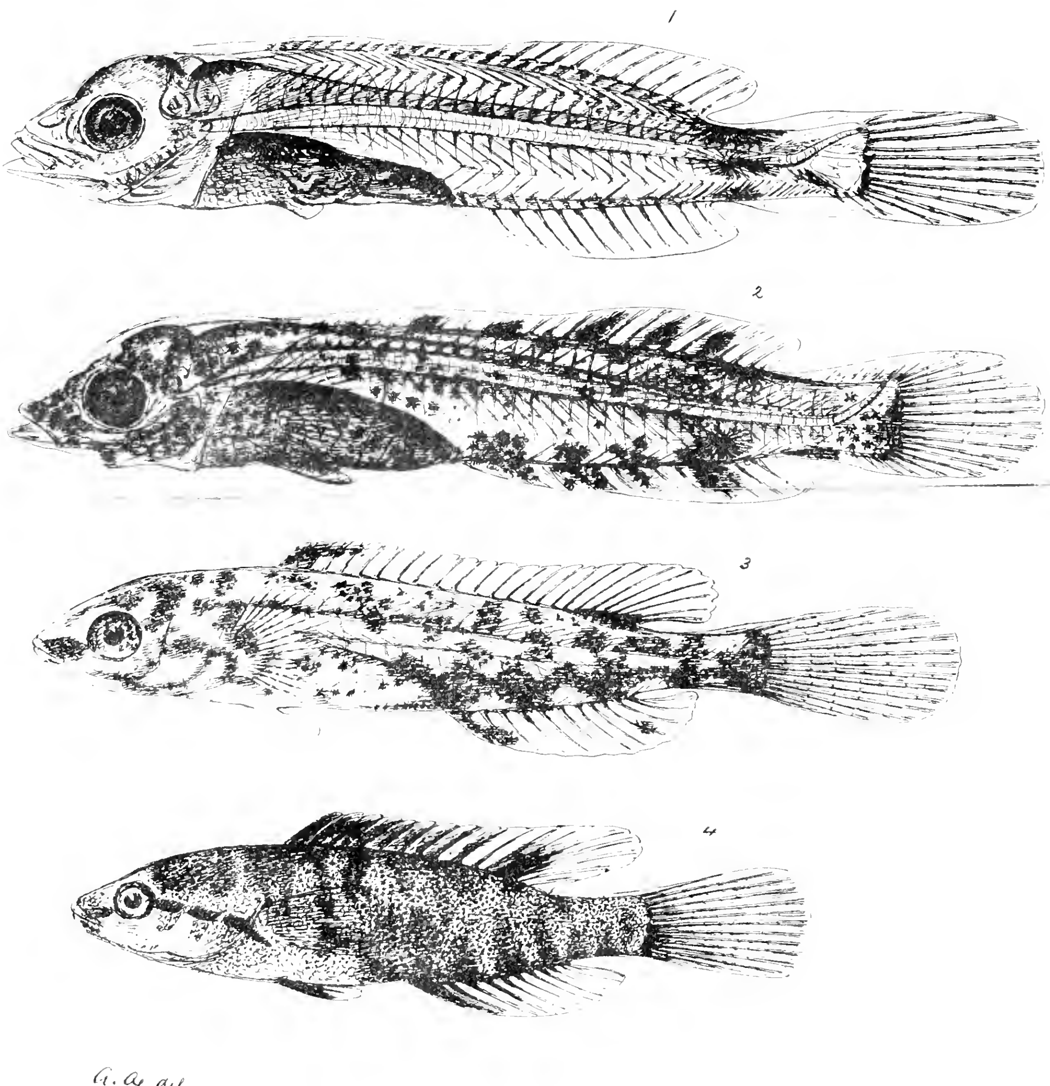
Agassiz Young Oceanic Fishes

Pl. XV



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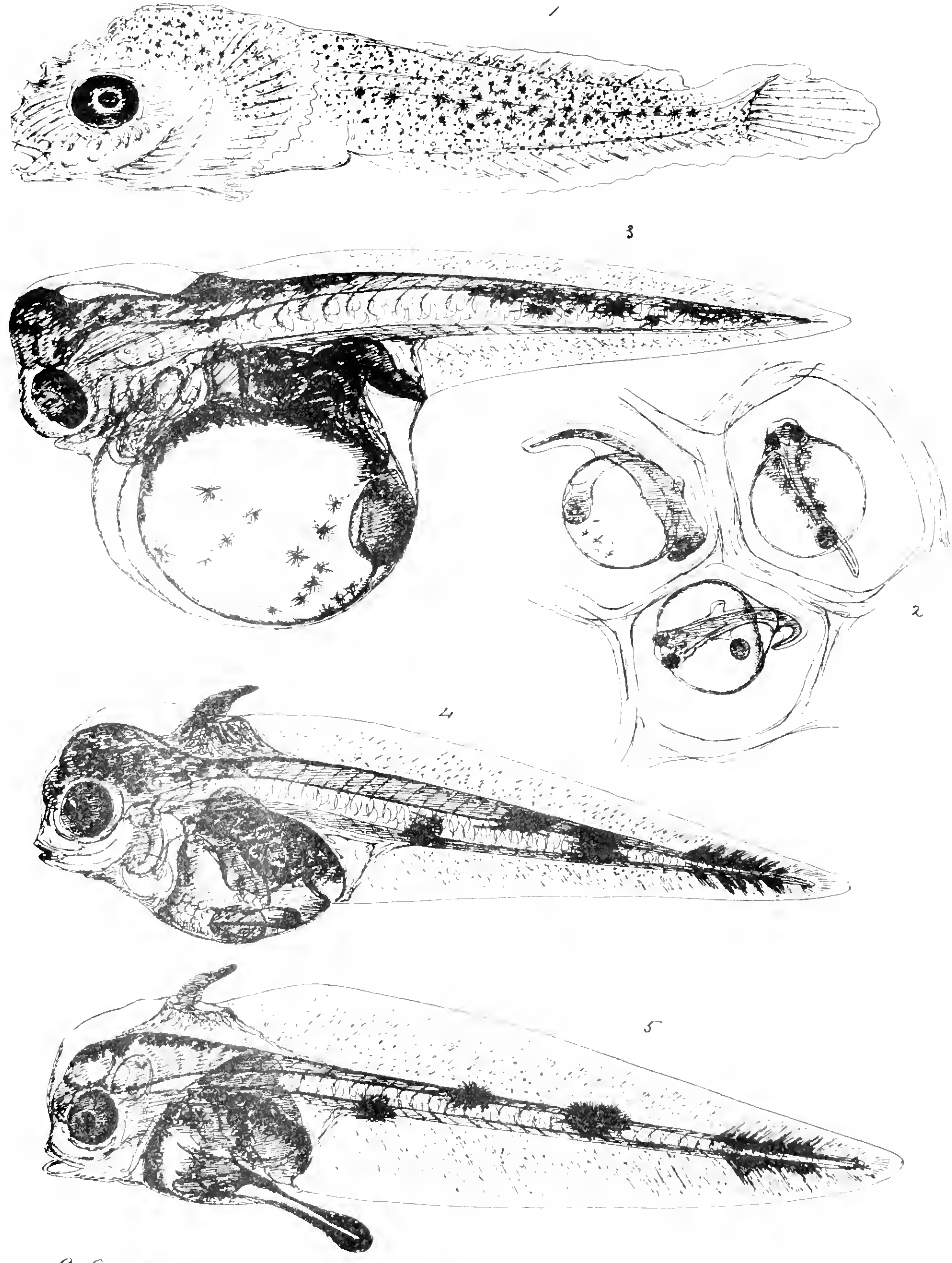
Agassiz Young Osseous Fishes

Pl. XVI



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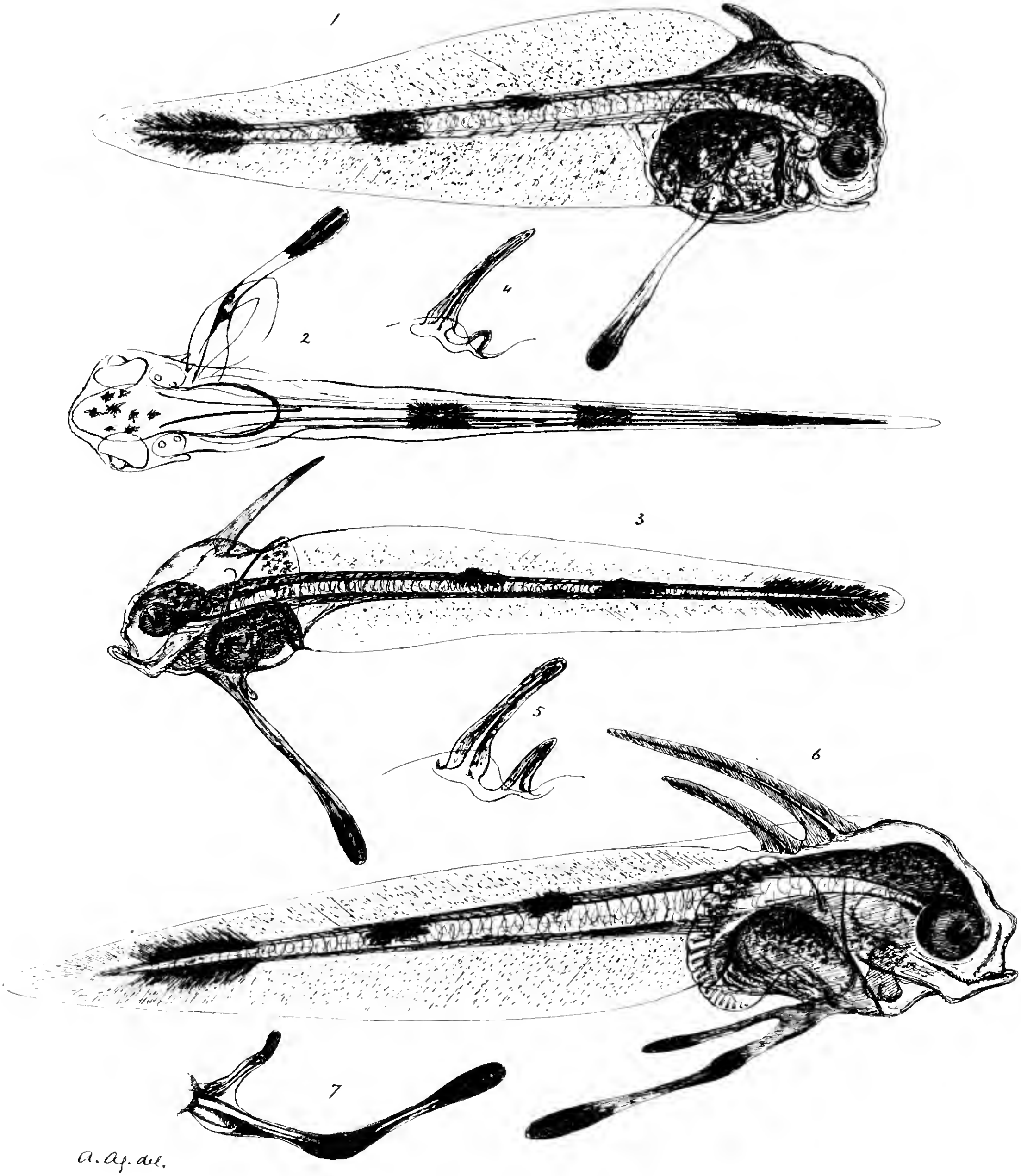
Agassiz Young Osseous Fishes. Pl. XVII



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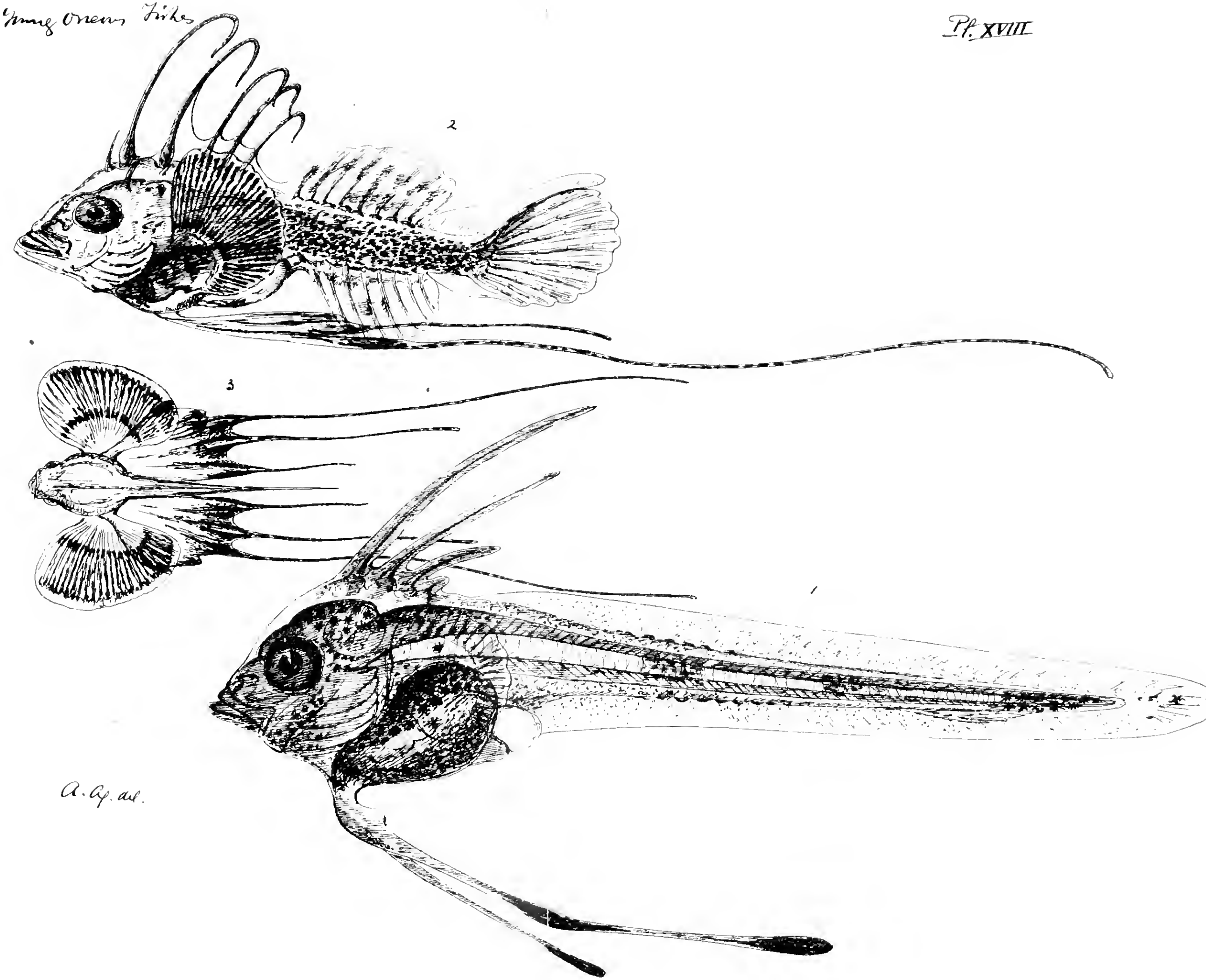
Agassiz Young Ocean Fishes

Pl. XVIII



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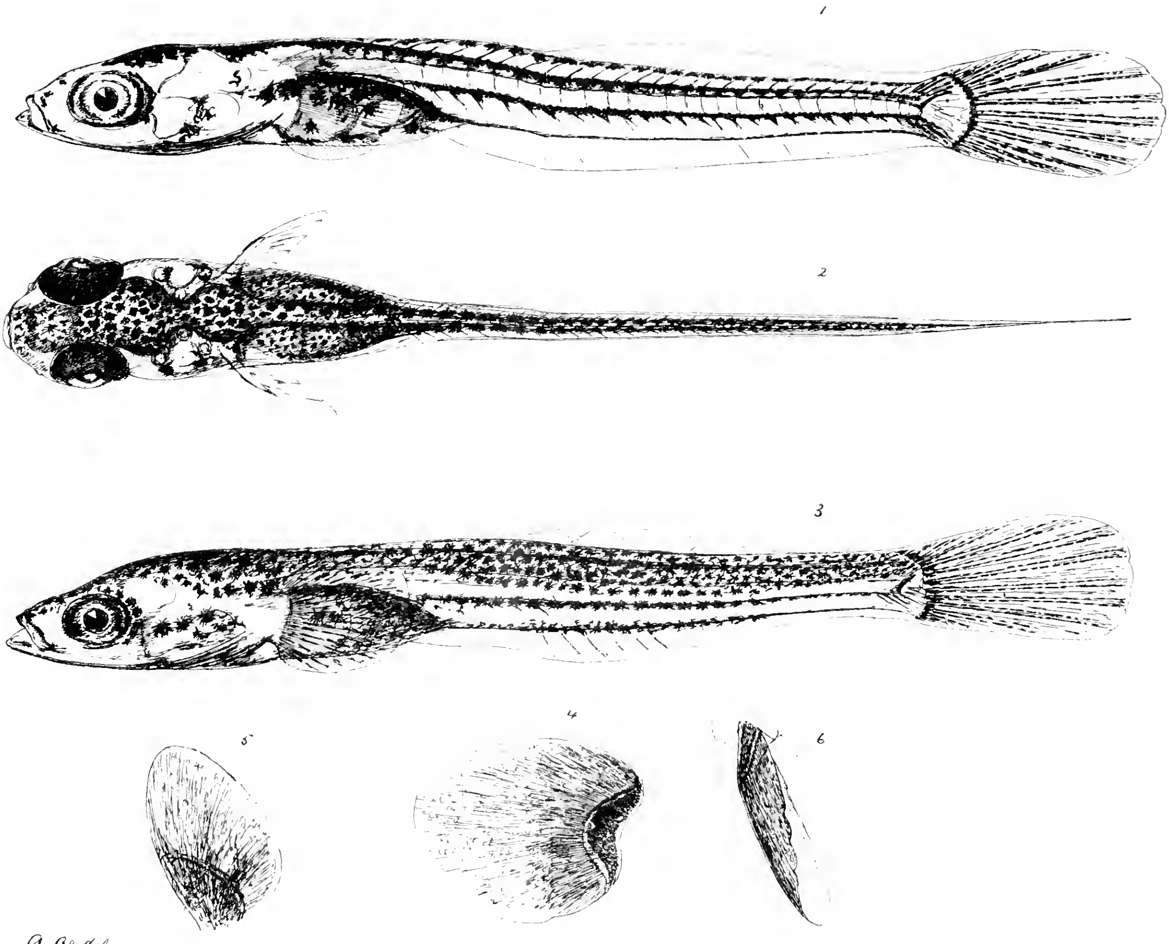
Agassiz Young Osseous Fishes

Pl. XIX



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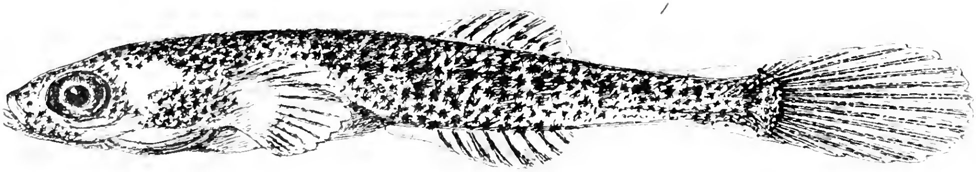
Agassiz Young Ocean Fishes

Pl. XX

1



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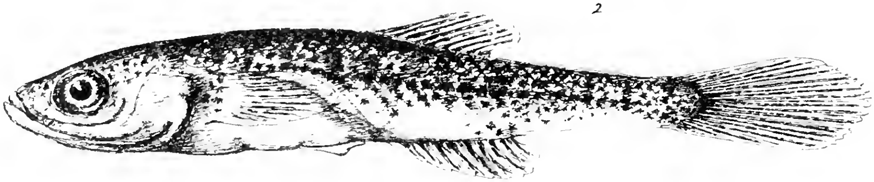

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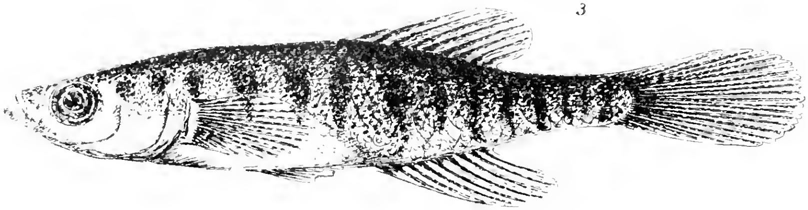

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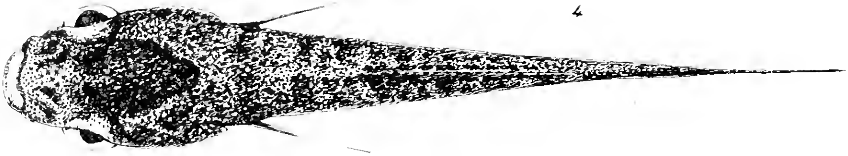

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EXPLANATION OF THE PLATES.

PLATE I.

LABRAX LINEATUS, *Bl. & Sch.* (ROCCUS, *Gill.*)

Fig. 1. Young Labrax measuring 3.5^{mm} in length.
" 2. Slightly older than fig. 1, measuring 4^{mm} in length.
" 3. Still more advanced, measuring nearly 5^{mm} in length.
" 3*a*. Tail of young Labrax somewhat older than stage of fig. 3, with a dorsal line of pigment spots.
" 4. Young Labrax in which caudal is forming, 8^{mm} in length.
" 5. Somewhat more advanced than fig. 4.

PLATE II.

Fig. 1. Young COTTUS GRŒNLANDICUS, somewhat older than stage of Plate III. fig. 5, measuring 8^{mm} in length.
" 2. Profile view of young Cottus measuring 11.5^{mm} in length.
" 3. Young Labrax 16^{mm} in length.
" 4. Young Labrax 26^{mm} in length.
" 5. Young Blue Fish (TEMNODON SALTATOR) measuring 9^{mm} in length.

PLATE III.

COTTUS GRŒNLANDICUS, *C. & V.*

Fig. 1. Egg of Cottus found floating on the surface.
" 1*a*. First trace of pectorals of young Cottus still within the egg.
" 1*b*. Somewhat older stage of lateral fold.
" 1*c*. Still older stage than fig. 1 *b*, still within the egg.
" 2. Young Cottus just hatched, measuring 2.5^{mm} in length.
" 3. Slightly older specimen, third day after hatching, seen from above.
" 4. Young Cottus, somewhat older than preceding stage, measuring 3^{mm} in length.
" 5. Young Cottus eleventh day after hatching.

PLATE IV.

CYCLOPTERUS LUMPUS, *Lin.*

Fig. 1. Young Lumpus, seen in profile, measuring 4^{mm} in length.
" 2. Same seen from above.
" 3. Young Lumpus, somewhat older than preceding stage, seen in profile.
" 4. Profile view of young Lumpus measuring 5^{mm} in length.
" 5. Profile of young Lumpus measuring 10^{mm} in length.

PLATE V.

Cyclopterus lumpus, *Lin.*

Fig. 1. Young Lumpus 20^{mm} in length.
" 2. The same as fig. 1, seen from above.
" 3. Profile of young Lumpus still older, measuring 34^{mm} in length.
" 3*a*. Spiny protuberances along anterior dorsal line of anterior dorsal.
" 3*b*. Largest spiny protuberances of lateral line.
" 3*c*. Pectorals and ventrals seen from the abdominal side.
" 4. Same as fig. 3, seen from above.

PLATE VI.

Poronotus triacanthus, *Gill.*

Fig. 1. Young Butterfish 7^{mm} in length.
" 2. Somewhat older stage than fig. 1.
" 3. Older stage than fig. 2; 9^{mm} in length.
" 4. Slightly more advanced than fig. 3; 10^{mm} in length.
" 5. Young Butterfish having principal characters of the adult, 16^{mm} in length.

PLATE VII.

Motella argentea, *Rhein.*

Fig. 1. Young, measuring 4^{mm} in length.
" 2. Somewhat older than fig. 1, 5^{mm} in length, seen in profile.
" 3. Same as fig. 2, seen from below to show rays of ventrals.
" 4. Young, measuring 7.5^{mm} in length.
" 5. Young, measuring 12^{mm} in length.
" 6. Slightly older than fig. 5, measuring 14.5^{mm} in length, seen in profile.

PLATE VIII.

Motella argentea, *Rhein.*

Fig. 1. View from above of same embryo as Plate VII. fig. 6.
" 1*a*. Same as fig. 1, seen from above, with its ventrals fully expanded and spread out.
" 2. Young Motella with small anterior dorsal, measuring 15^{mm} in length.
" 3. Considerably older than fig. 2, measuring 34^{mm} in length.
" 4. Young Gadus measuring 25^{mm} in length.
" 5. Young Cod measuring 28^{mm} in length.

PLATE IX.

Gasterosteus aculeatus, *Lin.*

Fig. 1. Young Gasterosteus with prominent ganoid tail fin measuring 7^{mm} in length.
" 2. Older stage, 12^{mm} in length, in which the embryonic fin lobe has disappeared, the tail fin has become symmetrical, and the permanent rays of the dorsal and anal are well developed.

Fig. 3. Slightly older than preceding stage. Rudiments of anterior dorsal spines and of ventrals have made their appearance, 15^{mm} in length.
" 4. In this stage the rudimentary anterior dorsal spines, as well as ventrals, have increased somewhat in length, the dorsal and anal are both higher, and the chromatophores of the body are arranged in bands somewhat as in the adult, 22^{mm} in length.
" 5. Young Gasterosteus, in which the principal characteristics of the adult are fairly developed, 27^{mm} in length.
" 5*a*. Anterior spine of ventral of young Gasterosteus, somewhat older than preceding stage.

PLATE X.

Atherinichthys notata, *Günth.* (Chirostoma, *Gill*).

Fig. 1. Young Atherina measuring 5^{mm} in length.
" 2. Somewhat older stage, measuring 6.5^{mm} in length, seen from above.
" 3. About in stage of fig. 2, seen in profile.
" 4. Older than preceding stage, 9^{mm} in length.

PLATE XI.

Atherinichthys notata, *Günth.*

Fig. 1. Somewhat more advanced than preceding stage (Plate X. fig. 4) $10,5^{mm}$ in length.
" 2. Young Atherina measuring 16^{mm} in length.
" 3. Young Atherina, having the principal characters of the adult, of about the same length as fig. 2.

PLATE XII.

Osmerus mordax, *Gill.*

Fig. 1. Young Osmerus just hatched, measuring 5^{mm} in length, seen in profile.
" 2. Same seen from above.
" 3. Young Osmerus measuring 9^{mm} in length.
" 4. Considerably older than fig. 3; 22^{mm} in length.
" 5. Oldest Osmerus found swimming on the surface, measuring 22^{mm} in length.

PLATE XIII.

Ctenolabrus cœruleus, *Dek.*

Fig. 1. Young just hatched from the egg, 2^{mm} in length.
" 2. Young, on the second day after hatching, 3^{mm} in length.
" 3. Young on the third day after hatching.
" 4. Young on the third day after hatching, somewhat older.
" 5. Young hatched four days, about 4^{mm} in length, seen in profile.
" 6. Young same as fig. 5, seen from above.

PLATE XIV.

CTENOLABRUS CŒRULEUS, *Dek.*

Fig. 1. Young 5^{mm} in length, fished up at the surface. Caudal fin forming.
" 2. Young 6^{mm} in length, anal and dorsal fins separated from the caudal, ventrals commencing to form.
" 3. Young 6.5^{mm} in length, somewhat more advanced than fig. 2.
" 4. Young measuring 7^{mm} in length, the dorsal and ventrals somewhat better separated from the caudal fin than in the preceding stage.
" 5. Young 10^{mm} in length.

PLATE XV.

CTENOLABRUS CŒRULEUS, *Dek.*

Fig. 1. Young somewhat more advanced than the stage of Plate XIV., fig. 5, of about the same length.
" 2. Young 11^{mm} in length.
" 3. Young 15^{mm} in length.
" 4. Young of same size as preceding figure, but somewhat more advanced.

PLATE XVI.

Fig. 1. Young BATRACHUS TAU, measuring 8^{mm} in length.

LOPHIUS PISCATORIUS, *Lin.*

Fig. 2. Three eggs embedded in the gelatinous membrane in which they are laid; magnified.
" 3. Young Lophius taken out of the egg just previous to hatching.
" 4. Young Lophius just after hatching.
" 5. Somewhat older stage; the yolk bag has entirely disappeared.

PLATE XVII.

LOPHIUS PISCATORIUS, *Lin.*

Fig. 1. Slightly older stage than fig. 5, Plate XVI.
" 2. Same as fig. 1, seen from above.
" 3. Older than fig. 1; the second ray of ventrals commences to form.
" 4. Anterior dorsal of slightly older stage, showing the beginning of the second ray.
" 5. Anterior dorsal rays of specimen somewhat older than fig. 4.
" 6. Older stage than fig. 5, with longer dorsal rays in anterior fin and rudiment of third; two large ventral rays.
" 7. Ventral rays of specimen somewhat older than fig. 3, about in the stage of fig. 5.

PLATE XVIII.

Lophius piscatorius, *Lin.*

Fig. 1. Young Lophius showing still greater increase in length and number of anterior dorsal and ventral rays.
" 2. Oldest pelagic stage, measuring 30mm in length, seen in profile.
" 3. Same seen from above, slightly less magnified.

PLATE XIX.

Fundulus nigrofasciatus, *C. & V.*

Fig. 1. Young, measuring 7mm in length.
" 2. Same seen from above.
" 3. Older than fig. 1; dendritic pigment cells more numerous in the upper part of the head; the nearly unbroken lines of chromatophores are broken up into separate cells; the permanent rays of the dorsal and anal fins make their appearance.
" 4. Crossopterygian stage of pectoral of young Fundulus about in stage of fig. 1, from the side.
" 5. Same fin seen from above, slightly bent laterally when in motion.
" 6. Same fin seen from above, at rest.

PLATE XX.

Fundulus nigrofasciatus, *C. & V.*

Fig. 1. Young measuring 11mm in length and uniformly covered with dendritic chromatophores, dorsal and anal quite high, well separated from the caudal; first trace of ventrals.
" 2. Young measuring 16mm in length, body more compact, ventrals quite distinct, anal and dorsal slightly lobed, caudal rounded, pectoral elongated, whole body covered uniformly by closely packed dendritic chromatophores.
" 3. Young measuring 20mm in length; although the head is still comparatively larger than in fig. 4, yet the anterior part of fish has assumed the characteristic sloping outline of the adult. The scales are already well developed in this stage. The pigment cells are comparatively smaller than in younger stages, and very closely packed over the whole surface, especially on the dorsal side.
" 4. Same as fig. 3, seen from above.

XVII.

CONTRIBUTIONS FROM THE PHYSICAL LABORATORY OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

XVI. EXPERIMENTS ON THE FATIGUE OF SMALL SPRUCE BEAMS.

By F. E. Kidder.

Presented May 10, 1882.

The following experiments were undertaken with the object of determining if possible what part of the so-called breaking load of a beam would ultimately cause the beam to break, all the conditions being the most favorable.

Incidental to the experiments, the moduli of rupture and of elasticity of small beams of kiln-dried spruce were determined.

The experiments were made in the Physical Laboratory of the Massachusetts Institute of Technology, the testing-machine used being the same as that described in a paper by the writer presented to the Academy Feb. 9, 1881.

With this machine the loads are applied by suspending known weights directly from the centre of the beam. The deflections of the beams were measured by means of a micrometer screw, the principle of electrical contact being taken advantage of in reading it. The moduli given have been computed from deflections measured to thousandths of an inch or hundredths of a millimetre.

As the load was suspended from a bolt resting upon the beam at the centre, it was necessary to measure the deflections one inch from the centre. For the small deflections from which the moduli of elasticity were determined, the difference between the measured deflection and the actual deflection is so small that it would not come within the limit to which the deflection was measured. For the deflections given in the tables, the deflections at the centre would be somewhat larger, but the error does not practically affect the results.

As the room in which these experiments were made is kept very warm and dry, any unseasoned timber would be so affected by the heat that it would be impossible to tell whether the deflections were caused entirely by the load, or partly by the heat of the room; hence it was thought best in making these experiments to use kiln-dried timber.

The small beams upon which the experiments were made were taken from two spruce planks, selected from lumber which had been cut in Maine during the previous season. The planks were kept in a drying-kiln three weeks, and were then cut up into pieces about two inches square and allowed to dry until tested. For convenience the beams cut from one plank are classed as Series No. 2, and those from the other as Series No. 3; Series No. 1 including those beams previously experimented upon, which were discussed in my previous paper.

All the pieces of wood experimented upon were what might almost be called perfect pieces, being straight grained and free from knots. They were about $1\frac{1}{2}$ inches square, and 40 inches between the supports. The exact dimensions, with other data, are shown in the tables.

TABLE I.

Series No. 1. Unseasoned Spruce.

No. of test piece.	Clear span *l*.	Breadth *B*.	Depth *D*.	*E*.	*R*.	Centre breaking weight for beam, 1″ × 1″ × 1′. *A*.	Deflection just before breaking.
	in.	in.	in.	lbs.	lbs.	lbs.	in.
1	40	1.475	1.45	1,731,000	11,380	632	1.565
2	40	1.445	1.52	1,556,000	10,330	574	1.395
3	40	1.469	1.448	1,765,000	10,710	595	1.48*
4	40	1.42	1.498	1,736,000	10,830	601	1.466
5	40	1.45	1.485	1,688,000	11,980	665	1.579
6	40	1.48	1.44	1,795,000	11,040	613	....
7	40	1.464	1.46	1,682,000	10,570	587	....
8	40	1.42	1.48	1,647,000	11,280	626	1.571
9	40	1.46	1.46	1,704,000	11,180	621	1.425
10	40	1.441	1.46	1,616,000	12,440	691	1.81*

Average value of *E*, 1,692,000 lbs.
" " " *R*, 12,170 lbs., of *A*, 620 lbs.
* Approximately.

Tables I., II., and III. are so arranged that a comparison of the strength and stiffness, together with the ultimate deflection of the pieces in the different series, can easily be made.

TABLE II.

SERIES NO. 2. KILN-DRIED SPRUCE.

No. of test piece.	Clear span *l*.	Breadth *B*.	Depth *D*.	*E*.	Deflection just before breaking.	*R*.	Centre breaking weight for beam, 1″ × 1″ × 1′. *A*.
	in.	in.	in.	lbs.	in.	lbs.	lbs.
1	40	1.52	1.52	1,573,000	1.676	12,560	698
2	40	1.495	1.5	....	1.656	13,590	755
3	40	1.52	1.5	....	1.517	12,540	697
4	40	1.51	1.503	....	1.816	13,720	762
5	40	1.506	1.506	....	1.662	13,740	763
6	40	1.51	1.516	1,760,000	1.937	Broke under $\frac{3}{4}$ b. w.	
7	40	1.508	1.508	1,636,000	1.79	Broke under $\frac{2}{3}$ b. w.	
8	40	1.51	1.518	1,721,000	....	Carried $\frac{2}{3}$ b. w. 22 days.	
9	40	1.5	1.504	1,580,000	....	Tested with $\frac{1}{2}$ b. w.	

Average value of *E* for five pieces, 1,654,000 lbs.
" " " *R* " " " 13,230 "
" " " *A* " " " 735 "

The letter *E* is used to denote the modulus of elasticity in these tables, and *R* the modulus of rupture.

The quantity denoted by *A* is one eighteenth of the modulus of rupture.

It will be noted that the pieces in Series No. 1 were not kiln dried, but were taken from a plank selected from ordinary timber.

TABLE III.

SERIES NO. 3. KILN-DRIED SPRUCE.

No. of test piece.	Clear span *l*.	Breadth *B*.	Depth *D*.	Deflection just before breaking.	*R*.	Centre breaking weight for beam, 1″ × 1″ × 1′. *A*.
	in.	in.	in.	in.	lbs.	lbs.
1	40	1.54	1.535	1.59	10,500	583
2	40	1.54	1.54	1.654	10,596	588
3	40	1.545	1.54	1.638	10,644	591
4	40	1.54	1.545	1.42	8,487	471
5	40	1.54	1.54	1.575	9,200	511
6	40	1.54	1.532	1.607	Broke under $\frac{3}{4}$ b. w.	
7	40	1.54	1.54	1.567	Broke under $\frac{2}{3}$ b. w.	
8	40	1.541	1.541	....	Tested with $\frac{1}{2}$ b. w.	

Average value of *R*, for five pieces, 9,885 lbs.
" " " *A*, " " " 549 "

Series No. 2.

In commencing this series of experiments five of the beams were subjected to loads of 30 and 40 lbs., and the deflection measured at the end of one hour from the time the load was applied. From these deflections the moduli of elasticity have been calculated. The values given in Table II. are the average of the values obtained from the deflection under 30 lbs. and the deflection under 40 lbs.

Having determined the moduli of elasticity of these pieces, five pieces of the series were broken by means of a gradually increasing load, and from their breaking load the modulus of rupture of each piece was computed. The average value of these five pieces (Nos. 1–5) was then considered to be the average value for the whole series, and the breaking weight of the remaining pieces of the series was computed on this basis.

Before attempting to break the remaining pieces, a load of 50 lbs., about $\frac{1}{15}$ of its breaking load, was applied to piece No. 6, with the object of determining if the deflection under this slight load would continually increase. The load was kept on the beam 288 hours, and the deflections, taken at intervals, are given in Table IV. From these it will be seen that the deflection increased very rapidly for the first 24 hours, and then quite regularly, but slowly, for 192 hours, and that after that it continued to *decrease* for 72 hours, when it slightly increased again.

As it was desired to use the machine for the more direct purposes of the experiments, the piece was removed from the machine, but it would have been interesting to have watched the further action of the load on the beam.

During the time that the deflections *decreased*, the weather was very wet, and it is the opinion of the writer that the deflections were somewhat affected by the change in the condition of the atmosphere. It should be observed that the greatest increase of deflection was very small, being only 0.44 of a millimetre, or about 0.017 of an inch.

After allowing this same beam several days in which to recover from the strain caused by the load of 50 lbs., 574 lbs., or $\frac{3}{4}$ of its calculated breaking load, was suspended from the beam, and the deflection measured at frequent intervals, with the results shown in Table IV. After carrying the load 260 hours the beam broke.

TABLE IV.

DEFLECTIONS OF PIECE No. 6, SERIES No. 2, UNDER A CONTINUED LOAD.

Load of 50 lbs. — $6\frac{1}{2}$ per cent. of Breaking Weight.					
Time applied.	Deflection.	Time applied.	Deflection.	Time applied.	Deflection.
hours.	mm.	hours.	mm.	hours.	mm.
0	2.04	120	2.305	240	2.408
24	2.22	144	2.368	264	2.358
72	2.265	168	2.418	288	2.368
96	2.283	192	2.478	Load removed.	
Load of 574 lbs. or $\frac{3}{4}$ of Calculated Breaking Weight.					
Time applied.	Deflection.	Time applied.	Deflection.	Time applied.	Deflection.
hours.	mm.	hours.	mm.	hours.	mm.
0	25.51	69	33.83	140	38.17
1.5	28.72	75	34.33	165	39.83
4.5	30.58	92	35.28	188	40.58
19.5	31.72	117	37.17	237	41.59
				260*	42.47
* Broke shortly after.					

Piece No. 7 of this series was computed to hold 756 lbs. before breaking, and 504 lbs., or $\frac{2}{3}$ of the breaking weight, was suspended from the beam. After supporting this load 134 hours the beam broke.

TABLE V.

DEFLECTIONS OF PIECE No. 7, SERIES No. 2, UNDER 504 LBS. OR $\frac{2}{3}$ OF ITS CALCULATED BREAKING WEIGHT.

Time applied.	Deflection.	Time applied.	Deflection.	Time applied.	Deflection.
hours.	mm.	hours.	mm.	hours.	mm.
0	23.04	48	34.43	120	43.16
14	28.48	86	38.06	134	45.46
24	31.26	96	40.04	Broke soon after.	
38	33.16	110	41.64		

The deflections of the beam measured at frequent intervals are given in Table V.

Piece No. 8 of this series carried $\frac{2}{3}$ of its breaking weight 499 hours, with an increase in deflection of 7.64 millimetres (0.3 in.).

As the deflection was constantly increasing, and was already more than the deflection of Piece No. 7 when the load was first applied, it seems to the writer that the beam would undoubtedly have in time been broken by its load.

The deflection of this beam is given in Table VI.

TABLE VI.

DEFLECTIONS OF PIECE NO. 8, SERIES NO. 2, UNDER 511 LBS. OR $\frac{2}{3}$ OF ITS CALCULATED BREAKING WEIGHT.

Time applied.	Deflection.	Time applied.	Deflection.	Time applied.	Deflection.
hours.	mm.	hours.	mm.	hours.	mm.
0	21.98	211	26.86	403	29.15
44	23.07	235	27.09	427	29.37
68	25.45	259	27.82	451	29.48
92	25.78	283	28.14	475	29.53
116	25.94	308	28.53	499	29.62
140	26.20	332	28.81	Weight taken off.	
168	26.43	379	29.02		

The last piece in Series No. 2, Piece No. 9, was subjected to a load of $\frac{1}{2}$ of its breaking weight for 327 hours, during which time the deflection constantly increased from 16.39 mm. (0.644 in.) to 19.07 mm. (0.75 in.). The load was then removed and the "set" of the beam measured. This set gradually decreased as the beam recovered itself, until it was quite small, and probably the larger part of it was due to the indentation of the beam at the points of support, something which cannot well be prevented in a wooden beam. It will be seen from table VII., that each time the load was applied the beam deflected a little more than at the previous application of the load; also that the set increased much faster than the deflection.

This tends to prove that the continued application and removal of one half of the breaking weight of a beam will in a comparatively short time cause it to break.

TABLE VII.

Experiments on Piece No. 9, Series No. 2.

Deflection under 374 lbs. or ½ of its Calculated Breaking Weight.

Time applied.	Deflection.	Time applied.	Deflection.	Time applied.	Deflection.
hours.	mm.	hours.	mm.	hours.	mm.
0	16.39	48	17.96	211	18.74
2	17.08	66	18.08	234	18.87
18	17.49	116	18.17	279	18.91
25	17.77	138	18.34	303	19.01
42	17.86	164	18.43	327*	19.07

* Load removed.

Recovery of the piece on removal of the above load after 327 hours application.

Time to recover.	Set.	Time to recover.	Set.	Time to recover.	Set.
hours.	mm.	hours.	mm.	hours.	mm.
0	2.41	8	1.73	48	1.32
2	1.94	24	1.46	74	1.30*
4	1.74	32	1.38		

* At least .5 mm. of this set was due to the indentation of the beam at the points of support.

After 21 days rest the beam was again put in the machine, and the same load of 374 lbs. was alternatively applied and taken off, with the following results: —

Weight.	Deflection on application of load.	Time applied.	Deflection.	Set.	Time to recover.	Set.
lbs.	mm.	hours.	mm.	mm.	hours.	mm.
374	16.62	26	18.22	1.45	16	.53
"	17.34	8	18.54	1.60	15	.66
"	17.52	4½	18.49	1.70	15½	.67
"	17.75	9½	18.83	1.90	14½	.97
"	17.95	9½	19.00	1.97	14½	1.08
"	18.10	48	19.56	2.68	24	1.48
"	18.38	9½	19.52	2.50	14½	1.47
"	18.38	9½	19.48	2.40	14½	1.53
"	18 58	9	19.73	2.60	15	1.54
"	18.70	48	20.35	3.15	9	1.67
"	19.15	24	20.86	3.40	15	1.75
"	19.55	24	22.02	4.30	24	2 26
"	20.12	24	21.86	4.20	9	3.97
"	21.85	756	26.80	7.70	24	5.61
"	24.90	105	27.16	7.40	24	5.70

Note. — The numbers in column 5 show the set of the beam immediately after the removal of the load, which was suspended from the beam during the number of hours given in column 3.

Series No. 3.

The results of the second series of experiments convinced the writer that a perfect and dry spruce beam would in time break under a load of only one half of its calculated breaking weight, but to make the results more certain a third series was undertaken, with the same object in view.

The pieces of wood tested in this series were to all appearance equally as perfect and dry as those in Series No. 2. Table III. gives the dimensions of the beams in this series, the moduli of rupture of the first five pieces, and the ultimate deflection of all the pieces.

The average value of the modulus of rupture of the first five pieces was taken as the basis from which the breaking weight of pieces Nos. 6, 7, and 8 were computed.

Piece No. 6 of this series was broken by a load of $\frac{3}{4}$ of its calculated breaking weight, 22 days after the load was applied. The deflections of this beam at various intervals during the 22 days are given in Table VIII.

TABLE VIII.

DEFLECTION OF PIECE NO. 6, SERIES NO. 3, UNDER A LOAD OF 399 LBS. OR $\frac{3}{4}$ OF ITS CALCULATED BREAKING WEIGHT.

Time applied.	Deflection.	Time applied.	Deflection.	Time applied.	Deflection.
days.	mm.	days.	mm.	days.	mm.
0	19.12	5.5	25.31	17.5	31.53
0.5	21.53	6.5	25.40	19.5	33.84
1.5	22.90	10.5	27.40	20.5	36.05
3.5	24.85	12.5	28.79	21.5	39.09
4.5	25.25	13.5	29.09	22*	40.82

* Broke within 12 hours.

The next piece of the series, No. 7, was subjected to a load of $\frac{2}{3}$ of its breaking weight, which it carried $24\frac{1}{2}$ days, and then gave way as the others had done.

The deflections are given in Table IX.

TABLE IX.

Deflection of Piece No. 7, Series No. 3, under a Load of 401 lbs. or $\frac{2}{3}$ of its Calculated Breaking Weight.

Time applied.	Deflection.	Time applied.	Deflection.	Time applied.	Deflection.
days.	mm.	days.	mm.	days.	mm.
0	20.07	9.5	31.68	18.5	33.19
1.5	23.77	10.5	31.93	19.5	33.28
3.5	26.98	11.5	32.04	20.5	33.58
4.5	29.70	12.5	32.30	23	35.57
5.5	30.37	15.5	32.70	23.5	37.04
6.5	30 80	16.5	32.85	24.5*	39.80
8.5	31.40	17.5	33.07		

* Broke within 12 hours.

Having proved that $\frac{2}{3}$ of the so-called breaking weight of a beam is more than it will carry permanently, the next beam was subjected to only $\frac{1}{2}$ of its calculated breaking weight.

This load was kept on the beam 49 days, during which time the deflection increased from 13.4 mm. (0.527 in.) to 18.55 mm. (0.73 in.) It was then necessary to remove the beam from the machine, that the latter might be used for other tests. The "set" of the beam on the removal of the load was 4.35 mm. (0.171 in.).

Seven days after the load was removed it was again put on the beam, and allowed to remain 77 days, when it was again removed, that the beam might be put on a temporary frame and kept there, with the same load suspended from it, until it broke.

The "set" of the beam on the second removal was only 3.76 mm. (0.148 in.), being less than what it was after the first removal.

The deflections of the beam are given in Table X.

As this beam continued constantly to deflect, and as this increase in deflection is still going on, it seems to the writer that it must ultimately break under this load, for when the deflection reaches a certain limit it will, as is shown by the other pieces, rapidly increase until it breaks.

Observations on Tables I., II., *and* III. Comparing Tables II. and III., we find a great difference in the values of the moduli of rupture for the two sets of experiments, although the planks from which the pieces were cut were selected from the same lot of lumber and dried the same length of time.

TABLE X.

Deflection of Piece No. 8, Series No. 3, under a Load of 301 lbs. or ½ of its Calculated Breaking Weight.

Time applied.	Deflection.	Time applied.	Deflection.	Time applied.	Deflection.
days	mm.	days.	mm.	days.	mm.
0	13.40	14	16.77	25	17.14
1	15.03	15	16.93	26	17.17
3	15.51	17	16.89	27	17.41
4	15.58	18	16.89	29	17.51
6	16.34	19	16.97	31	17.59
8	16.52	20	17.07	33	17.76
10	16.53	21	17.14	38	17.97
11	16.66	22	17.14	45	18.45
12	16.83	24	17.10	49	18.55
13	16.79				

After taking the last deflection the load was removed from the beam, when the centre of the beam returned to within 4.35 mm. of its original position. After 7 days the load of 301 lbs. was again put on the beam, causing the following deflections: —

Time applied.	Deflection.	Time applied	Deflection.	Time applied.	Deflection.
days.	mm.	days.	mm.	days.	mm.
0	13.20	23	15.70	59	16.84
1	14.25	38	16.18	63	16.95
3	14.61	43	16.43	66	17.05
5	14.90	47	16.50	68	17.11
10	15.25	48	16.52	71	17.15
13	15.37	53	16.64	77	17.32
18	15.73	54	16.70		

The only reason which the writer can give for the low value of R in the third series is that the plank was sawn from the outside of the tree. It will be noticed that the values of R ran very high for the pieces in Series No. 2, also that the average value of R for Series No. 1 is only about 8 per cent less than that for Series No. 2, while it is about 23 per cent greater than the average for Series No. 3.

This would lead one to infer that ordinarily dry lumber does not have its strength materially increased by being kiln dried.

Comparing Tables I. and II., we see that the average value of the modulus of elasticity for the beams of unseasoned spruce is fully as large as that for the kiln-dried spruce. The beams in Table I., though denoted as unseasoned, were fully as dry as timber which has been in an ordinary building three months, but it was not artificially dried.

If we compare the ultimate deflections of all the pieces with their moduli of rupture, we shall find as a rule that those beams which were the strongest bent the most before breaking.

The values of E in Tables I., II., and III. were computed from the expression $E = \frac{Wl^3}{4\Delta BD^3}$, Δ denoting the deflection in inches. The values of R were computed from the formula $R = \frac{3}{2}\frac{Wl}{BD^2}$.

From further observations of the tables we shall see that the deflections of Pieces Nos. 6 and 7 of Series No. 3 increased 100 per cent; or the deflection when the load was applied was only about ½ what it was when the beam broke.

Also that the deflection of Piece No. 9, Series No. 2, and of Piece No. 8, Series No. 3, is much less than one half of what the ultimate deflection would probably be.

Hence I think it perfectly safe to conclude that for spruce-beams of small section a load which will produce a deflection of one half the maximum deflection of the beam before breaking will ultimately break the beam.

From a study of Tables VII. and X. it appears that a load of one half the so-called breaking load of a beam does not injure the beam when applied only for a short time; for it will be noticed that for both Pieces No. 9, Series No. 2, and Piece No. 8, Series No. 3, the deflection of the beam upon the second application of the load was almost the same as upon the first application, the difference being very slight indeed.

Effect of the "Annual Rings" on the Strength of a Beam.

After computing the moduli of rupture for the first five pieces of Series No. 2, the writer was surprised to see that three pieces had nearly the same modulus, and that the remaining two pieces also agreed almost exactly, but that there was a great difference between the moduli of the three and of the two pieces.

The writer could think of no reason for this phenomenon until he examined the fractured section of the beams, when it was discovered that in the three beams which had the high moduli the "annual rings" were parallel, or nearly so, with the top and bottom surfaces of the beam, while in the other two the "annual rings" made an angle of about 45° with these surfaces.

Conclusions.

The conclusions which may be drawn from the research here described, the writer considers to be as follows: —

That for spruce beams of small section, selected from lumber which has been moderately well seasoned and dried, the strength is not materially increased by the timber being kiln dried; that the modulus of elasticity is not proportional to the modulus of rupture; and that the elasticity is not increased by kiln-drying the timber.

That with small spruce beams those which have the greatest strength bend the most before breaking.

That when a load between $\frac{1}{2}$ and $\frac{7}{8}$ of the so-called breaking weight is applied to a small spruce beam it produces a deflection which for a few hours rapidly increases, until the beam has fairly settled under its load; from this time the deflection increases gradually until a short time before breaking, when it increases more and more rapidly.

That a load of $\frac{1}{2}$ of the so-called breaking weight if applied but for a few days does not injure such beams.

That a load which will cause such a beam to deflect one half of its maximum deflection before breaking will ultimately break the beam.

That under the most perfect conditions small spruce beams will not permanently support a load of one half their so-called breaking weight.

That the position of the annular rings in spruce beams of small section materially affects the strength of the beams, their strength being the least when the rings make an angle of 45° with the top and bottom surfaces of the beam.

The writer agrees with Prof. R. H. Thurston in considering 5 as the least factor of safety which should be used for wooden beams under an absolutely static load.

XVIII.

CONTRIBUTIONS TO AMERICAN BOTANY.

By Sereno Watson.

Presented May 5, 1882.

1. *List of Plants from Southwestern Texas and Northern Mexico, collected chiefly by Dr. E. Palmer in* 1879–80. — I. *Polypetalæ.*

Dr. Edward Palmer's present collection was made during the last six months of 1879, mostly in the region lying northwest of San Antonio, Texas, and along the routes from that place to Laredo and Eagle Pass upon the Rio Grande, and during the following year in the States of Coahuila and Nuevo Leon in Mexico. A nearly complete set of these plants was sent to the herbarium at Kew, England, and a partial list was there somewhat hastily made, which is the basis of the present one. In addition, determinations are given of an excellent collection made by Dr. J. G. Schaffner in the State of San Luis Potosi (likewise partially named at Kew), as well as of some plants received from Professor Alfred Dugès of Guanajuato, and as occasion serves the numbers of the previous collection of Parry & Palmer in Northern Mexico are also cited. The numbers under which Palmer's collection was distributed by him are included in parentheses under the species. The *Cactaceæ* have been kindly named by Dr. Engelmann, so far as their determination was possible, and continual use has been made of the recent catalogue of the Mexican flora by Mr. W. B. Hemsley in the botanical volumes of the "Biologia Centrali-Americana" of Godman and Salvin, which has proved a very material assistance.

Clematis Drummondii, Torr. & Gray. At Uvalde, Texas (3), and Parras, Coahuila (1); also specimens with smaller leaves from Laredo on the Rio Grande (2), nearly equivalent to *C. nervata*, Benth., which is a more silky-pubescent form, and the same as 2 Parry & Palmer. The species varies considerably in the size and form of the leaves.

Clematis Pitcheri, Torr. & Gray. At Laredo, Texas (7), and from several localities in Coahuila (4, 5, 6, 8), in as many different forms, the last number corresponding to 1 Parry & Palmer, referred to *C. filifera*, Benth., which is to be considered a synonym. This polymorphous species, ranging from Western Illinois to Central Mexico (Guanajuato, from Dugès), is extremely variable in its foliage. The leaflets, usually four pairs, may be either ternate or 3-lobed, or all simple and entire, broadly ovate or cordate to lanceolate, and usually acute, but sometimes very obtuse or long-acuminate. The flowers vary from 9 to 18 lines in length.

Thalictrum strigillosum, Hemsl. At Lerios, Coahuila (9). Apparently one of the more common Mexican species, and probably to be identified with some older one. Ghiesbreght's specimen from Chiapas, referred by Hemsley to *T. longistylum*, also belongs here. Dr. Schaffner collects in the San Miguelito Mountains two very distinct species which are not readily identified. Both are glabrous, one having ascending peduncles bearing close heads of sessile triangular carpels, which are 1½ lines long, with thickened and rib-like angles, the other polygamous, with long recurved peduncles and open heads of 2 to 9 pedicellate compressed carpels beaked with a long style.

Anemone Mexicana, HBK. Santa Rosa Mountains, Guanajuato (Dugès).

Ranunculus geoides, HBK. A low species, silky-pubescent, with the radical leaves 3-lobed. A single specimen was collected at Guajuco, Nuevo Leon.

Ranunculus Hookeri, Schlecht. In the San Miguelito Mountains (183 Schaffner); 6 and 1030 Parry & Palmer. This species, if rightly understood, is a common one in Mexico. The mature carpels have usually a few more or less prominent scattered tubercles upon the sides.

Ranunculus stolonifer, Hemsl. Near Morales, San Luis Potosi (185 Schaffner); 4 Parry & Palmer.

Ranunculus delphinifolius, HBK. In the San Miguelito Mountains (184 Schaffner), and at Guanajuato (Dugès).

Aquilegia longissima, Gray. in herb. Somewhat pubescent with silky hairs: stem three feet high: leaves deeply lobed with narrow segments, glaucous beneath, green above: flowers "lake, white, and straw-color," the lanceolate sepals broadly spreading, 12 to

15 lines long, the petals spatulate, about 9 lines long, the claw opening by a narrow orifice into the very slender elongated spur, which is 4 inches long or more. — In the Caracol Mountains, south of Monclova, Coahuila (10). Allied to *A. cærulea* and *A. chrysantha*, but distinguished from both by the narrower petals and the constricted mouth of the much more elongated spur.

Delphinium leptophyllum, Hemsl. In the San Miguelito Mountains (27 Schaffner); Guanajuato (Dugès); 7 Parry & Palmer.

Delphinium azureum, Michx. Guajuco, Nuevo Leon (11). Apparently not differing from slender few-flowered forms of this variable species.

Cocculus Carolinus, DC. San Antonio, Texas (12).

Cocculus diversifolius, DC. (*C. oblongifolius*, DC.) Laredo, on the Rio Grande, Texas (13). Both with oblong and with ovate-cordate leaves, representing the two forms figured by Moçino & Sesse and described by De Candolle.

Berberis Schiedeana, Schlecht. (*Mahonia trifolia*, Cham. & Schlecht.) In the Sierra Madre, forty miles south of Saltillo (14). The specimens accord very closely with Schlechtendal's description, except that the leaves are all trifoliolate, as in Schiede's original specimens. The racemes are short, about equalling the petioles. The *Mahonia ilicina* of Schlechtendal (*Berberis*, Hemsl.), at first supposed by him to be this species, he afterward identified (Bot. Zeit. 12. 655) with *B. pallida*, Hartw.

Berberis trifoliolata, Moric. In the same locality (15), and also at Lerios, forty-five miles east of Saltillo (16).

Berberis gracilis, Hartw., var. With the 5 to 7 leaflets often rounded at base and the racemes shorter (1 or 2 inches long). In the San Miguelito Mountains (711 Schaffner); 8 Parry & Palmer.

Nymphæa ampla, DC. At San Lorenzo de Laguna, Coahuila (17), and at Monclova (18).

Argemone platyceras, Link & Otto, Icon. Pl. Rar. Hort. Berol. i. 85, t. 43. (*A. hispida*, Gray.) At Saltillo (19); 10 Parry & Palmer. A probable variety was also collected at Parras (20), with the large flowers of a decided pink color, and the seeds less than a line long, scarcely more than half of the usual size.

Argemone fruticosa, Thurber. At San Lorenzo de Laguna, Coahuila, in flower and fruit (21). The flowers, which have not before been collected, are noted as sulphur-yellow, and are $2\frac{1}{2}$ to 3 inches in diameter. The beaks of the sepals are large and conical, terminating in stout rigid spines.

Bocconia frutescens, Linn. At Guajuco, Nuevo Leon (23).

Hunnemannia fumariæfolia, Sweet. At Monterey, Nuevo Leon (22); 1031 Parry & Palmer.

Fumaria parviflora, Lam. At Saltillo (24); 9 Parry & Palmer.

Nasturtium tanacetifolium, Hook. & Arn. At San Lorenzo de Laguna, Coahuila (34), and near Corpus Christi Bay, Texas (35); San Luis Potosi (148 Schaffner); 11 Parry & Palmer.

Arabis runcinata. Biennial, hirsute with simple spreading hairs, low and branching: leaves runcinately lyrate, petiolate, the lobes acute and acutely toothed; lower leaves 4 inches long: flowers small ($1\frac{1}{2}$ lines long), on hispid petioles, the calyx glabrous: pods ascending, an inch long by a line wide, beaked by the long style, few- (about 10-) seeded: seeds elliptical, winged. — In shaded places about San Luis Potosi (155 Schaffner). Allied to *A. petiolaris*, Gray.

Arabis Mexicana. Very slender, glabrous, decumbent: leaves lyrately pinnatifid, the few lateral lobes narrow, distant, mostly entire, the terminal one 2- or 3-toothed or -lobed: racemes elongated in fruit, the flowers very small (a line long), white, on slender spreading pedicels a line or two long: pods ascending, 5 to 8 lines long by half a line broad, abruptly beaked by a rather conspicuous style, the valves reticulately veined, obscurely 1-nerved toward the base: seeds in one row, round, narrowly wing-margined. — Near Guanajuato (Dugès), where it is popularly known as "Lantejuelilla," and considered injurious to cattle eating it.

Cardamine auriculata. Annual, erect or ascending, slender, branching, a span high, very sparingly hispid: leaflets three pairs, petiolulate, ovate or the terminal one oblong-ovate, crenate, about half an inch long or less, often with a small subsidiary auricle or stipule-like leaflet on the lower side at the point of union with the rhachis of the leaf: flowers white, 2 lines long: pods an inch long by half a line broad, ascending on pedicels about 3 lines long, and attenuate above into a long slender style. — At Guajuco, Nuevo Leon (49). Most resembling *C. impatiens*. The *Cardamine Schaffneri*, Hook. f. in Hemsl. Diag. Pl. Nov. 1. 2, is the same as *C. Gambelii*, Watson.

Vesicaria purpurea, Gray. Caracol Mountains, Coahuila (29). Flowers white, becoming pink. A low doubtful form, with yellow flowers, was found in the Sierra Madre, Coahuila (28), and at Monterey, Nuevo Leon (32).

Vesicaria argyrea, Gray. In the Sierra Madre, Coahuila (30); a slender form with narrow leaves, and a taller and stouter form with broader conspicuously toothed leaves. 25 Parry & Palmer, referred to this species by Hemsley, is rather *V. recurvata*, Engelm.

VESICARIA FENDLERI, Gray. (*V. stenophylla*, Gray.) In the Sierra Madre, Coahuila (31).

VESICARIA SCHAFFNERI. Biennial, with several or numerous ascending or decumbent stems, 6 to 15 inches high, simple or branched, canescent throughout with a close scurfy pubescence: leaves linear- to oblong-oblanceolate, obtuse or acute, entire or with one or two teeth on each side, very variable in size (½ to 3 inches long): petals pale yellow or at length purplish, 3 lines long, twice longer than the linear sepals: pod glabrous, globose (narrower at base when young), about 2 lines long, very shortly stipitate, erect on the slender and at length horizontal pedicel, which is about 4 lines long; style about a line long. — On mountains and in shaded places near San Luis Potosi (150 Schaffner, in large part; 26 and 25½ mainly, Parry & Palmer; mixed with *V. argyrea*). With the habit nearly of *V. Gordoni*, which however, like *V. argyrea* and most of the allied species, has an evidently stellate pubescence.

COCHLEARIA (?) MEXICANA. Annual, erect and slender (6 inches high or less), the stem branching above and puberulent: leaves shortly petiolate, ovate, truncate or usually cuneate at base, sparingly toothed, the cauline 6 to 12 lines long, including the petiole: flowers very small, in a flexuose raceme, the yellowish-white spatulate petals (a line long) twice longer than the green sepals: style very short, and stigma capitate: pods glabrous, globose, nearly sessile upon spreading pedicels (2 lines long), 1 to 1½ lines in diameter; valves nerveless: seeds 4 in each cell, subglobose. — At Monterey, Nuevo Leon (40). Referred with some hesitation to this genus (§ *Kernera*), with which it accords as well as with any other. The filaments are straight and naked, with conspicuous glands at base; cotyledons accumbent.

SISYMBRIUM CANESCENS, Nutt. Near San Luis Potosi (153 Schaffner). 683 Coulter, referred to *S. streptocarpum*, is the same.

SISYMBRIUM COULTERI, Hemsl. Near San Luis Potosi (154 Schaffner, in part, with the following); 14 Parry & Palmer.

SISYMBRIUM PALMERI, Hemsl. The typical form, with dense hoary pubescence and undulate-toothed leaves, the lower lyrate. Also var. ELATIUS, Hemsl., taller (1 or 2 feet high), less canescently pubescent and somewhat villous, the leaves thinner and greener, not undulate, the lower large but scarcely lyrate, all strongly auricled; pods somewhat longer (9 to 12 lines) and pedicels rather shorter (2 to

6 lines). Near San Luis Potosi (154 Schaffner, in part); 13 Parry & Palmer.

ERYSIMUM ASPERUM, DC. In the Sierra Madre, Coahuila (48).

THELYPODIUM LONGIFOLIUM, Watson. Hispid below with spreading hairs: lower leaves unknown, the upper narrowly linear: sepals glabrous, broad and very concave, 2 to 2½ lines long; petals a little longer, oblong, scarcely narrower below: pod very slender, 1½ to 2½ inches long by ½ line broad, beaked by the slender style, spreading or usually pendent upon the slender pedicel (3 to 6 lines long). — In the San Miguelito Mountains (156 Schaffner, in part). This is 52 Hartweg, 687 Coulter, and perhaps 22 Fendler.

THELYPODIUM MICRANTHUM. (*Streptanthus micranthus*, Gray.) Biennial, erect (2 to 3 feet high), more or less stellately pubescent: lower and cauline leaves oblanceolate, sinuately pinnatifid, stellately pubescent, attenuate to a petiole, the upper linear, entire, usually glabrous: flowers smaller than in the last (1 to 1½ lines long), the calyx glabrous or pubescent: pod slender, about an inch long, sessile, nearly terete, the style very short and thick, ascending or sometimes pendent, on pedicels 2 to 4 lines long. — In the Sierra Madre, Coahuila (37), and at San Luis Potosi (156 Schaffner, in part). This includes 23 Fendler, 844 Wright, 610 Rothrock, and 281 Pringle, all of which have been referred to the preceding species.

THELYPODIUM AURICULATUM. (*Sisymbrium auriculatum*, Gray.) In the Sierra Madre, Coahuila (25), and at Lerios (50). The only partially incumbent cotyledons, together with the characters of the pods and flowers, and the general habit, seem to require the transfer of this species to *Thelypodium*.

THELYPODIUM LINEARIFOLIUM, Watson. At Saltillo (36).

ERUCA SATIVA, Lam. At Saltillo (2144), and near San Luis Potosi (152 Schaffner); 16 Parry & Palmer.

GREGGIA CAMPORUM, Gray. At San Lorenzo de Laguna (27), and Monclova, Coahuila (44), and at Monterey, Nuevo Leon (47). A low form with narrow entire leaves was collected at Parras (46); 17 Parry & Palmer.

SYNTHLIPSIS BERLANDIERI, Gray, var. HISPIDA. More or less villous, with little stellate pubescence, the ovary densely hairy, and the pod more loosely so. — Near Corpus Christi Bay, Texas (26). This is the same as 157 and 1417 Berlandier, from Laredo in Tamaulipas, and appears to differ from the typical form only in the pubescence.

SYNTHLIPSIS HETEROCHROMA. Procumbent and much resembling ordinary forms of *S. Berlandieri*, more or less canescent with stellate pubescence, and sometimes sparingly villous: flowers bright yellow by day, becoming brownish purple at night: ovary pubescent and more or less villous; pod round-obovate (2½ to 4 lines broad), sometimes shortly stipitate. — At Monterey, Nuevo Leon (33). The pod of *S. Berlandieri* is always sessile, and rounded or almost emarginate at base.

SYNTHLIPSIS GREGGII, Gray. At Parras (45); 18 Parry & Palmer. 149 Schaffner, from the San Miguelito Mountains, has usually shorter pods, sometimes scarcely longer than broad. Dr. Gregg's original specimens include the same form.

CAPSELLA PUBENS, Benth. & Hook. At Parras, Coahuila (39).

CAPSELLA MEXICANA, Hemsl. In swampy places near Morales (147 Schaffner); 19 Parry & Palmer.

CAPSELLA (?) SCHAFFNERI. Annual, glabrous or nearly so, erect and somewhat branched mostly from near the base, 4 to 8 inches high, the stem and branches angled and the angles usually slightly pubescent: cauline leaves linear-oblanceolate, obtuse or truncate or retuse, sessile, 4 to 6 lines long, entire or with a few short blunt teeth: flowers white, the petals 2 lines long: fruiting pedicels ascending, 1–2½ lines long: pod shortly stipitate, oblong-lanceolate, somewhat obcompressed, the valves strongly convex, more or less evidently nerved and carinate, 1½ or 2 lines long and beaked by a slender style ½ line long: seeds 4 or 5 in each cell; cotyledons probably accumbent. — San Miguelito Mountains (151 Schaffner). A plant of very uncertain affinities, and perhaps belonging among the *Sisymbrieæ* near *Smelowskia*. The pod varies much, but is decidedly obcompressed when well developed, especially toward the base. In the present uncertain limits of *Capsella* the species may as safely be placed here provisionally as elsewhere.

LEPIDIUM LASIOCARPUM, Nutt. (*L. Wrightii*, Gray.) Low (6 inches high or less), pubescent throughout with short spreading hairs, the straight pedicels shorter than the pod, stout and much flattened. — Var. TENUIPES. Usually taller, more slender, and less pubescent, the pod glabrous: pedicels narrower and more slender, as long as or usually exceeding the pod. At Parras (41), and San Luis Potosi (145 Schaffner). The same as 21 and 22 Parry & Palmer (referred to *L. Menziesii*), and 686 Coulter and 14 Bourgeau. in part (named *L. Virginicum*), and of frequent occurrence through the interior northward to Nevada and Southern Colorado. It has the habit of *L. intermedium*, Gray (23 Parry & Palmer), with which it has been confounded, but is readily distinguished by the flattened pedicel. It might be regarded as a distinct species, but is connected with *L. lasiocarpum* by intermediate forms, such as those collected at Monterey (38, 42), and 2488 Berlandier (*L. ruderale*, var. *lasiocarpum*, Engelm.).

Lepidium Menziesii, DC. At Monterey (43); San Luis Potosi (146 Schaffner). Also 14 Bourgeau, in herb. Gray, mostly.

Cristatella erosa, Nutt. At Lamar, on Copano Bay, Texas (51). *C. Jamesii*, Torr. & Gray, may perhaps be distinguished by smaller flowers and shorter pods (an inch long or less). The genus, however, should be reduced to a section of *Polanisia*.

Polanisia uniglandulosa, DC. At Soledad, Coahuila (52); also San Luis Potosi (192 Schaffner), and Guanajuato (Dugès).

Polanisia trachysperma, Torr. & Gray. At Laredo on the Rio Grande (54), the typical form, with style 3 or 4 lines long and seeds more or less roughened. Also in the mountains north of Monclova, Coahuila (53), a common form with shorter styles (a line or two long) and smoother seeds; flowers white, becoming pink.

Oligomeris glaucescens, Camb. At Saltillo (1149).

Helianthemum Coulteri. Stems short (3 to 6 inches high), erect from a branched and spreading woody caudex: leaves oblanceolate ($\frac{1}{2}$ to $1\frac{1}{2}$ inches long by 2 to 6 lines broad), acutish, attenuate at base to a very short petiole, rough above with a short stellate pubescence, densely soft-tomentose beneath, conspicuously pinnate-veined: flowers large (an inch broad), shortly pedicelled in rather close corymbs, the acute sepals 3 or 4 lines long: capsule broadly triangular-ovate, a little shorter than the calyx. — At Zimapan (743 Coulter) and in the Morales Mountains, San Luis Potosi (608 Schaffner). It is referred by Hemsley to *H. arenicola*, Chapm., which has narrower leaves, softly pubescent on both sides and not evidently nerved, flowers on longer pedicels and subumbellate, and capsule narrower.

Helianthemum patens, Hemsl. In the San Rafael Mountains (605 Schaffner); 30 Parry & Palmer.

Helianthemum glomeratum, Lag. In the San Miguelito Mountains (137 Schaffner); 28 Parry & Palmer.

Helianthemum argenteum, Hemsl. In the San Miguelito Mountains (606 Schaffner); 29 Parry & Palmer.

Lechea major, Michx. In the San Rafael Mountains (Schaffner).

Lechea Skinneri, Benth. In the San Rafael Mountains (604 Schaffner): 31 Parry & Palmer.

Viola flagelliformis, Hemsl. At Lerios, Coahuila (56), and in the San Miguelito Mountains (182 Schaffner); 1033 Parry &

Palmer. The flowers are described as "rosei" by Dr. Schaffner. 36 Parry & Palmer, referred to *V. pubescens*, is the same, and 736 Coulter (*V. latistipula*, Hemsl.) appears to be an undeveloped form of it.

VIOLA HOOKERIANA, HBK. In the San Miguelito Mountains (180 Schaffner); 34 Parry & Palmer.

VIOLA BARROETANA, Schaffn. In the San Miguelito Mountains (181 Schaffner); 35 Parry & Palmer.

VIOLA CUCULLATA, Ait.? At Saltillo, a single fruiting specimen with broadly deltoid leaves.

IONIDIUM VERBENACEUM, HBK.? In the Sierra Madre, Coahuila (55). These specimens accord nearly with the original figure and description, except that the leaves are mostly opposite. It is however described (not figured) as an annual, while this has an evidently perennial slender rootstock. The flowers are purple. 660 Ghiesbreght, from San Cristobal, appears to be the same. *I.* (?) *calceolarium*, Gingin, as represented in the drawing of Moçino & Sesse, is very similar, but with an apparently annual root.

IONIDIUM POLYGALÆFOLIUM, Vent. Wilson County, Texas (57). A puberulent form, with the stipules very small or obsolete. More pubescent specimens, with somewhat smaller flowers and well-developed stipules, were collected at Monterey. This species seems to include the original *I. lineare* of Torrey, and nearly all that has been referred to it.

AMOREUXIA WRIGHTII, Gray. At Laredo, on the Rio Grande (58), in fine fruit. To this species belongs 37 Parry & Palmer, as well as the specimens collected at Monterey by Eaton & Edwards, and in Sonora by Thurber, all referred by Hemsley to *A. palmatifida*, DC., with which *A. Schiedeana*, Planch., is identified. Aside from the ovate seed of the one and the reniform seed of the latter species, *A. Wrightii* may be known by the five broader lobes of the leaves, rather abruptly narrowed downward, the lower lobe often incised on the lower margin, while the leaves of the other have seven or nine lobes which are narrowed regularly to the base.

POLYGALA LINDHEIMERI, Gray. In the Sierra Madre, Coahuila (2143).

POLYGALA OVALIFOLIA, DC. At Monterey, Nuevo Leon (65); 43 Parry & Palmer.

POLYGALA PUBERULA, Gray. In the mountains west of Saltillo (64). Identical with specimens of Schiede & Deppe, referred to "*P. pubescens*, Muhl." Also a form with larger flowers at Saltillo

(66); 42 Parry & Palmer. 42½ Parry & Palmer is the more fertile form with nearly apetalous flowers.

POLYGALA PALMERI. Perennial, branching, 6 to 8 inches high, densely short-pubescent throughout: leaves scattered, oblong-oblanceolate, truncate and mucronate or abruptly acute, attenuate at base, mostly 6 to 9 lines long by 2 or 3 broad: racemes open and few-flowered: flowers pale greenish-yellow, 3 lines long, soon reflexed; sepals linear-lanceolate; wings pubescent and ciliate, ovate, acute, cuneate at base, about equalling the crestless keel; petals oblong, purplish: capsule flat, ovate, deeply emarginate, pubescent, 4 lines long. — At Juraz, Coahuila. Nearly allied to *P. Americana* and *P. puberula*, and much resembling forms of the latter species, but more pubescent, and with larger flowers and fruit.

POLYGALA OBSCURA, Benth. At Monterey, Nuevo Leon, sparingly collected; 41 and 44 Parry & Palmer.

POLYGALA GREGGII. Perennial (?), pubescent throughout, the stems very slender and terete, flexuous above and branching, about a foot high: leaves punctate, from oblong-spatulate to cuneate-obovate, obtuse or emarginate, 3 to 5 lines long: flowers few, 2 or 3 axillary near the end of a short leafy branchlet, white, 3 lines long; sepals narrowly lanceolate; wings slightly pubescent, cuneate-obovate, exceeding the narrowly oblong petals, which are longer than the keel and aduate to it half its length; keel without crest, the very broad and rounded lateral margins folded back and covering the hood: ovary pubescent, flattened, elliptical, emarginate. — West of Cerralbo (Gregg). A strongly marked species of this group, remarkable for the long petals and the broad reflexed margins of the keel.

POLYGALA MACRADENIA, Gray. At Juraz, Coahuila (70).

POLYGALA ALBA, Nutt. In the Sierra Madre, Coahuila (68); 39 Parry & Palmer. The lower leaves are often distinctly verticillate.

POLYGALA SCOPARIA, HBK. At Lerios, Coahuila (69). This is very probably also *P. Mexicana*, DC., but the drawing by Moçino & Sesse is too poor for positive identification. 45 Parry & Palmer, which is referred here, has very short round-quadrate capsules, but still exceeding the petals.

POLYGALA VIRIDIS. Minutely pubescent; stems several, erect or ascending from a biennial (?) root, 3 or 4 inches high: leaves scattered, oblanceolate, acute, attenuate at base, 3 to 5 lines long by 1½ or 2 broad: racemes terminal or often lateral, open, ½ to at length 2 inches long: flowers very small, nearly sessile; wings spatulate (a line long), green with a white margin, exceeding the strongly hooded keel; petals broadly oblong; crest broad, very unequally 2-lobed on each side: capsule glabrous, oblong, 1½ lines long, slightly inequilateral: caruncle of two linear lobes two-thirds of the length of the pubescent seed. — On Caracol Mountains, Coahuila (2013). Very nearly allied to *P. scoparia.* The crest is a broad triangular lamina on each side of the median line, to which it is attached, with a narrow lobe on the outer side.

POLYGALA SEMIALATA. Glabrous; stems numerous, very slender, angled, from an apparently biennial root, 3 to 6 inches high: leaves scattered, linear, acute at each end, 2 or 3 lines long: racemes terminal, very slender and open (1 to 3 inches long), the very small whitish flowers (little more than half a line long) nearly sessile and soon pendulous; wings broadly spatulate; petals truncate, nearly equalling the fimbriately crested keel: capsule similar to that of *P. hemipterocarpa*, but only 2 lines long, and the dehiscing cell more narrowly winged. — At Monterey, Nuevo Leon (67). With *P. hemipterocarpa* forming a section marked by the curious unequally developed fruit, one cell indehiscent and filled by the seed, the other doubly wing-margined, dehiscing between the wings, and at length unfolding.

KRAMERIA CYTISOIDES, Cav. (*K. cinerea*, Schauer.) In mountains east of Saltillo (59); 1043 Parry & Palmer.

KRAMERIA CANESCENS, Gray. At Soledad, Coahuila (61).

KRAMERIA PAUCIFLORA, DC. In the mountains east of Saltillo, single specimens; 38 Parry & Palmer. Distinguished from *K. secundiflora*, DC. (*K. lanceolata*, Torr.), as it is understood, by the uniformly shorter narrowly lanceolate leaves (3 or 4 lines long), and by the retrorse barbs along the more slender spines of the fruit.

KRAMERIA RAMOSISSIMA. Shrubby and divaricately much branched, a foot or two high, canescent: leaves linear-lanceolate, 1 or 2 (sometimes 3) lines long, often fascicled in the axils: flowers "light maroon": fruit ovate, silky-pubescent, with slender very acute naked spines about half a line long. — *K. parvifolia*, var. *ramosissima*, Gray, Pl. Wright. 1. 41. On mountains near Saltillo (62); also on the Rio Grande (Wright), at Camargo (Gregg), and in Nuevo Leon (Berlandier).

FRANKENIA GRANDIFOLIA, Cham. & Schlecht. At San Lorenzo de Laguna, Coahuila (60).

SILENE LACINIATA, Cav., var. with ovate leaves. (*S. Greggii*, Gray.) In the Sierra Madre, south of Saltillo (71). The form with linear leaves, at the other extreme, is the more common; in the San Miguelito Mountains (609 Schaffner); 46 Parry & Palmer.

Cerastium nutans, Raf. At Lerios, Coahuila; near San Luis Potosi (143 Schaffner); 47 Parry & Palmer.

Stellaria cuspidata, Willd. At Morales (124 Schaffner). The identification of this species with the European *S. nemorum*, Linn., is at least doubtful. It appears to have a more herbaceous and much more pubescent calyx, the leaves broadest nearer the base, and the seeds smaller and more coarsely tuberculate.

Stellaria prostrata, Baldw. At Guajuco, Nuevo Leon (77). Distinguished from the last by its annual root, more or less broadly ovate acute and usually smaller leaves, smaller and more glabrous calyx, and smaller seeds scarcely roughened on the sides.

Arenaria alsinoides, Willd. (*A. diffusa*, Ell. *A. lanuginosa*, Rohrb.) In the Sierra Madre, south of Saltillo (76), and near San Luis Potosi (135 Schaffner); 48 and 55½ Parry & Palmer. Also var. angustifolia, with leaves very narrowly linear (½ to 1 line wide), sometimes with broader ones at the lower nodes. A low form of this variety, with mostly simple 1–few-flowered stems and short pungent leaves, was collected at Saltillo. The species is very variable in its southwestern range, sometimes developing a diffuse regular dichotomously branched inflorescence.

Arenaria decussata, HBK. At Lerios, Coahuila (75), and in wet shady places near Morales (138 Schaffner); 61 Parry & Palmer.

Lepigonum * Mexicanum, Hemsl. (under the name *Spergularia*). In sandy places near San Luis Potosi (137 Schaffner); 52 Parry & Palmer. "Flowers pale yellow." Decidedly perennial, with a thick perpendicular root. The various forms in Schaffner's collection show that 58 Parry & Palmer ("*S. neglecta?*") is a stunted state of it.

Lepigonum rubrum, Fries. San Luis Potosi (137^b Schaffner).

Drymaria cordata, Willd. At Saltillo (79). Young specimens of what appears to be this species, distinguished by the rounded leaves, subtruncate at base, rarely at all apiculate at the rounded summit, the inflorescence lax and few-flowered, and the sepals ordinarily quite glabrous, 1 to 1½ lines long, acute and scarcely nerved. The stems are lax, from an annual root, at length rooting at the lower nodes.

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* This generic name is retained for the reasons that are given by Kindberg in his monograph of the genus. *Stipularia*, Haworth (1812), would strictly have precedence, but was long overlooked (even by Bentham & Hooker), and the name has been adopted for a Rubiaceous genus. *Lepigonum* was proposed by Fries in 1817. *Spergularia* was first taken up as a generic name by Presl in 1819.

Drymaria gracilis, Cham. & Schlecht. Stems very lax, from a perennial root, glabrous throughout: leaves cordate or deltoid-ovate, acute: inflorescence much branched and diffuse: sepals thin, nearly nerveless, acute or acutish, 1½ to 2 lines long. — San Luis Potosi (130 Schaffner, in part); Guanajuato (Dugès); also 57 Parry & Palmer, 21 and 2659 Bourgeau, 706 (?) and 710 Coulter.

Drymaria Fendleri. Annual; the erect or ascending stems and the petioles usually more or less pubescent: leaves broadly subreniform-cordate or the base sometimes truncate, acute or shortly acuminate: flowers on short pedicels and more or less fascicled, the pubescent and somewhat rigid sepals long-acuminate, distinctly 1–3-nerved, about 2 lines long. — From New Mexico and Arizona to Central Mexico; 60 Fendler (*D. cordata*, Gray, Pl. Fendl. 13); 866 Wright, also Thurber and Bigelow (*D. glandulosa*, Gray, Pl. Wright. 2. 18; Torrey, Pacif. R. Rep. 4. 70, and Bot. Mex. Bound. 37); Greene, 42 Rusby, and 510 Lemmon; near San Luis Potosi, 130 Schaffner, in part; Valley of Mexico, 552 (?) Bourgeau. Two other species of this group, more or less confounded with the preceding, may be characterized as follows: —

Drymaria villosa, Cham. & Schlecht. (*D. palustris*, Cham. & Schlecht.) Sparingly villous on the petioles, lower side of the leaves, and calyx: stems very lax and slender, from a slender rootstock, often rooting at the lower nodes: leaves subreniform-cordate, abruptly short-acuminate: inflorescence very lax and open: sepals thin-membranous, lanceolate, acute, 1 to 1½ lines long. — 944 Botteri; Sumichrast; cult. Hort. Kew.

Drymaria glandulosa, Bartl. (*D. ramosissima*, Schlecht.) Glandular-pubescent throughout: stems ascending or decumbent, from a stout rootstock: leaves triangular-ovate, acute or acuminate: inflorescence very diffuse: sepals rather rigid, lanceolate, acuminate, 1-nerved, 2 lines long. — 51 Parry & Palmer; 1308 Berlandier: Palmer (Carmen Island). The original of the species is described as an annual.

Drymaria suffruticosa, Gray, in herb. Suffrutescent at base, much branched, nearly a foot high, smooth and glaucous: leaves narrowly linear, 6 to 12 lines long: cymes few-flowered, terminal, the flowers large and reflexed: sepals ovate or rounded, 2½ lines long; petals included, fimbriately margined below, cleft above into several linear lobes: capsule broadly ovate: seeds surrounded by a conspicuous fimbriate crest. — At San Lorenzo de Laguna, Coahuila (74).

DRYMARIA POLYCARPOIDES, Gray. At the same locality (73, in part). Glaucous throughout: cymes terminal: seeds white and shining, almost transparent. Very distinct from the next.

. DRYMARIA CRASSIFOLIA, Benth. With similar glaucous foliage, but the internodes elongated and the slender pedicels fascicled in the axils: seeds nearly orbicular, dark brown, opaque. — Mixed with the last under the same number, in the Gray Herbarium set.

DRYMARIA NODOSA, Engelm., and var. ANGUSTIFOLIA, Hemsl. Near San Miguelito (140 Schaffner); 60 Parry & Palmer.

DRYMARIA ARENARIOIDES, Willd. (*D. frankenioides*, HBK.) Near Morales (139 Schaffner); 49 Parry & Palmer.

DRYMARIA XEROPHYLLA, Gray. Near Morales (131 Schaffner); 50 Parry & Palmer.

CERDIA PURPURASCENS, DC. San Luis Potosi (128 Schaffner).

CERDIA GLAUCA, Hemsl. In the Esculerillos Mountains (Schaffner); 63 Parry & Palmer.

CERDIA CONGESTIFLORA, Hemsl. In mountains near San Luis Potosi (Schaffner); 63½ Parry & Palmer.

ACHYRONYCHIA PARRYI, Hemsl. At Lerios, Coahuila, a single specimen; 53 Parry & Palmer.

PORTULACA PILOSA, Linn. At Laredo, on the Rio Grande (2141), and about San Luis Potosi (771 Schaffner); 66 Parry & Palmer. Also a peculiar form, probably distinct, with a thick fleshy root, small narrow leaves, 1 to 3 lines long, and very hairy in the axils, smaller flowers, and lighter-colored seeds; in the San Miguelito Mountains (772 Schaffner).

TALINOPSIS FRUTESCENS, Gray. In San Luis Potosi Valley (773 Schaffner); 67 Parry & Palmer.

TALINUM AURANTIACUM, Engelm. At Laredo, on the Rio Grande (2142), and San Luis Potosi (770 Schaffner); 68 Parry & Palmer.

FOUQUIERIA SPLENDENS, Engelm. In the mountains east of Saltillo (80), and at San Lorenzo de Laguna, Coahuila.

ELATINE AMERICANA, Nutt. Near Morales (122 Schaffner).

HYPERICUM PERFORATUM, Linn. At Sutherland Springs, Wilson Co., Texas (81).

HYPERICUM MUTILUM, Linn., var. (?) Leaves rounded to ovate-cordate, clasping; floral bracts narrowly linear: sepals very unequal, spatulate to oblong-oblanceolate, obtuse or acutish, 1½ to 2½ lines long, exceeding the ovate capsule: seeds acutish at each end, light-brown. — On Caracol Mountains, Coahuila (82). *H. philonotis*, Schlecht., is probably *H. mutilum*.

Hypericum denticulatum, HBK. About San Luis Potosi (607 Schaffner, in part); 72 Parry & Palmer.

Hypericum pauciflorum, HBK. Specimens which agree fairly with the original incomplete description of this species are collected by Dr. Schaffner, together with *H. denticulatum* and the following species. Parry & Palmer distributed it also with the next as n. 73, referred by Hemsley to *H. fastigiatum*, HBK. The whole plant is glaucous, the stem 4-angled, simple, 6 to 15 inches high: leaves from oblong-ovate or oblong-lanceolate below to linear above, ½ to 1 inch long: flowers few (3 to 12) in a terminal cyme, rather large, the lanceolate sepals 2 to 4 lines long, shorter than the petals: stamens about 50: styles 3 (rarely 4 or 5): capsule attenuate upward, exceeding the calyx.

Hypericum Schaffneri. Pale green, not glaucous: stems 4-angled, 6 to 18 inches high, branched above: leaves narrowly lanceolate, attenuate from a clasping base, ½ to 1 inch long: flowers numerous, often lateral along the elongated branches of the cyme; sepals linear, 1½ to 2 lines long, a little shorter than the narrow petals: stamens 5 to 10: styles very short: capsule oblong, acute or acutish, 2 to 2½ lines long. — Mountains near San Luis Potosi (607 Schaffner, in part); 73 Parry & Palmer, in part. Allied to *H. paniculatum* and *H. fastigiatum*.

Callirrhoe involucrata, Gray. At Lerios, Coahuila (86). Also var. lineariloba, Gray, from the same locality (85).

Callirrhoe pedata, Gray. In Burnet and Wilson counties, Texas.

Malvastrum tricuspidatum, Gray. At Uvalde, Texas (104).

Anoda hastata, Cav. (Including *A. cristata*, Schlecht.) At Soledad, Coahuila (106^a), and near San Luis Potosi (159 Schaffner); 76, 77 and 78 Parry & Palmer.

Anoda parviflora, Cav. Near Morales (158 Schaffner). Most readily distinguished from the last by the densely stellate-pubescent fruit and yellow flowers.

Sida hederacea, Gray, var. With coarsely-toothed leaves. At San Lorenzo de Laguna, Coahuila (92).

Sida fasciculata, Torr. & Gray. At Sutherland Springs, Wilson County, Texas (91).

Sida diffusa, HBK. (*S. filiformis*, Moric.) Both the typical hairy form, from Sutherland Springs, Texas, and a rough-puberulent variety, with broad-elliptical leaves, from Monclova, Coahuila (105); also in the San Miguelito Mountains (167 Schaffner); 87 and 89 Parry & Palmer. This name is adopted in the Kew list, and three seems to be no good reason for objection.

Sida Lindheimeri, Gray. Sutherland Springs, Texas (102).

Sida filipes, Gray. At Monclova, Coahuila (106).

Sida tragiæfolia, Gray. Mountains north of Monclova (103).

Sida physocalyx, Gray. At San Antonio, Texas (88), and at Parras, Coahuila (87). Two other undetermined species of this genus were collected by Schaffner in the San Miguelito Mountains (160) and near Morales (162).

Abutilon Texense, Torr. & Gray. A small-leaved form, from Laredo, on the Rio Grande (108). A variety (?) was collected by Dr. Palmer at Sutherland Springs, and has also recently been found by Dr. Havard in Western Texas, with large leaves roughish on the nerves beneath, paniculately many-flowered, the calyx roughish-pubescent and erect in fruit, and the carpels stellate-pubescent. In the ordinary form the calyx is reflexed in fruit.

Abutilon hypoleucum, Gray. At Monterey, Nuevo Leon (109), and a variety from Caracol Mountains, Coahuila, with the carpels less hispid (110).

Abutilon holosericeum, Scheele. At Soledad, Coahuila (111). Collected also at Monterey by Berlandier (148 and 1408) and by Eaton & Edwards. A variety (?), with the tomentum roughish throughout and the leaves less acuminate, was collected at Monclova, Coahuila (112).

Abutilon crispum, Don. In the San Miguelito Mountains (163 Schaffner).

Sphæralcea hastulata, Gray. At Saltillo (a solitary specimen), and in the San Miguelito Mountains (165 Schaffner). Also at Guadalupe, Texas, a variety with elongated pedicels (the same as 173 Berlandier), and in the mountains east of Saltillo a form with shorter ovate or oblong-ovate subhastate leaves (93). This species is distinguished from the next by its more slender habit, the several decumbent stems from a slender perennial rootstock, and by the larger calyx.

Sphæralcea angustifolia, St. Hil. The typical form of this species, as figured by Cavanilles (Icones, 1. 48, t. 68), is received from Dugès at Guanajuato, with large oblong-lanceolate leaves 3 to 5 inches long and extending nearly to the top of the stem, the large carpels rounded at the summit and not at all beaked, and their lateral walls obscurely or not at all reticulated. This is strictly Mexican, but does not appear in this collection, which includes instead several forms of the common polymorphous variety that ranges northward to

Colorado, the *S. stellata*, Torr. & Gray. This is marked especially by having the rather smaller carpels more or less rostrate, at least when young, and their sides strongly reticulated toward the base. It seems impossible, however, to draw a clear line between the two. The leaves are usually serrate and mostly somewhat hastately lobed; mountains near Saltillo (94, 95, 96, 98, 99, 100, 101), and at Monterey, Nuevo Leon. A form with entire and less undulate leaves was collected at Parras (97). The flowers vary in size, and in color from salmon to pink and magenta. It is popularly known to the Mexicans as "yerba del negro."

Pavonia lasiopetala, Scheele. (*P. Wrightii*, Gray.) At Uvalde, Texas (89), and a form with more acutely and deeply-toothed leaves at Monclova, Coahuila (90).

Malvaviscus Drummondii, Torr. & Gray. At San Antonio, Texas (115). Known as "May-apple," and the scarlet fruit eaten, both raw and cooked.

Hibiscus cardiophyllus, Gray. At Soledad, Coahuila (107).

Hibiscus Coulteri, Harv. At Saltillo, Coahuila (83).

Hibiscus denudatus, Benth., var. involucellatus, Gray. At Monclova, Coahuila (84). This is much the more common form.

Gossypium Barbadense, Linn. At San Lorenzo de Laguna, Coahuila (116). "Considered by some to be indigenous."

Hermannia Texana, Gray. At Juraz (113).

Melochia pyramidata, Linn. At Laredo, on the Rio Grande (117).

Ayenia microphylla, Gray. At Juraz, Coahuila (114).

Corchorus pilolobus, Link. At Guadalupe, Texas (119), and at Juraz, Coahuila (120.)

Tilia Mexicana, Benth. On Caracol Mountains, near Monclova, Coahuila (118).

Linum rupestre, Engelm. In the Sierra Madre, east and south of Saltillo.

Linum Greggii, Engelm. At Monterey, Nuevo Leon. A single specimen.

Linum rigidum, Pursh. At Monterey (122). More glaucous than *L. Berlandieri*, with narrower leaves and shorter calyx.

Linum Cruciata, Planch. At Guajuco, Nuevo Leon (121). Lower leaves very obtuse or slightly apiculate, only the uppermost glandular-toothed.

Linum lecheoides. Erect, leafy, hispid throughout, the stout purplish stems fastigiately branched toward the top, a foot high:

leaves sessile, narrowly oblong-lanceolate, acute, pubescent beneath, glabrous above, 4 to 6 lines long: corymbs few- (1–5-) flowered: sepals broadly ovate, acute, not ciliate, a line long or less; petals yellow, nearly twice longer: styles united at base: capsule ovate, acute, equalling the calyx. — In the San Miguelito Mountains, near San Luis Potosi (600 Schaffner).

LINUM SCABRELLUM, Planch. In the San Miguelito Mountains (603 Schaffner).

LINUM SCHIEDEANUM, Cham. & Schlecht. In the Morales Mountains (601 Schaffner); 103½ Parry & Palmer.

LINUM MEXICANUM, Kunth. At Guanajuato (Dugès).

MALPIGHIA GLABRA, Linn. On Corpus Christi Bay (157).

GALPHIMIA ANGUSTIFOLIA, Benth. (*G. linifolia*, Gray.) In mountains north of Monclova (128); 94 Parry & Palmer.

HIRÆA GREGGII. A shrubby climber, rather sparingly tomentose-pubescent: leaves opposite, ovate-elliptic, the uppermost oblong-ovate, very obtuse or acutish to abruptly short-acuminate, obtuse at base, somewhat pubescent beneath, roughish above, 6 to 18 lines long, the short petioles often 2-glandular: pedicels elongated: calyx glanduliferous; petals yellow, undulate-margined and somewhat erose: filaments short and stout, nearly equal, united to the middle: samara slightly pubescent, the lateral wings nearly semicircular, each an inch broad, distinct above and below, the dorsal one much smaller. — Near Monterey, Nuevo Leon (123), where it was also collected by Dr. Gregg in 1847.

HIRÆA LILACINA. A slender shrubby climber, somewhat pubescent with straight appressed hairs attached by the middle: leaves opposite, ovate to lanceolate, acute, rounded or cordate at base, on slender glandless petioles: pedicels opposite in terminal or axillary few-flowered racemes: calyx glanduliferous; petals "blue" or "lilac," entire or shortly fimbriate above: filaments slender, united only at base: samara hairy on the ventral side, orbicular-winged, the lateral wings together 9 lines broad, the dorsal much smaller. — On Caracol Mountains, south of Monclova (124); it has also been collected near Palomas (328 Gregg), and at Rinconada (Dr. Edwards).

GAUDICHAUDIA FILIPENDULA, Juss., var. (?) San Luis Potosi (901 Schaffner), and at Guanajuato (Dugès); 95 Parry & Palmer.

ASPICARPA HYSSOPIFOLIA, Gray. At Monclova and the neighboring Caracol Mountains; scanty specimens.

ASPICARPA HARTWEGIANA, Juss. In the Sierra Madre, south of Saltillo; scanty specimens.

Aspicarpa longipes, Gray. In the San Miguelito Mountains (902 Schaffner).

Janusia gracilis, Gray. In mountains north of Monclova (126).

Tribulus maximus, Linn. At Laredo, on the Rio Grande (131), and at Monclova, Coahuila (131[a]).

Sericodes Greggii, Gray. The flowers are golden yellow and fragrant. At San Lorenzo de Laguna (63), and at Soledad (321).

Larrea Mexicana, Moric. A variety with the leaves mostly bifid at the apex. At Saltillo, Coahuila (132).

Porlieria angustifolia, Gray. At San Antonio, Texas (129), and in the Sierra Madre, south of Saltillo (130); 97 Parry & Palmer.

Geranium Carolinianum, Linn. In the mountains near Penasco, San Luis Potosi (190 Schaffner); 101 Parry & Palmer. Very nearly the usual form of the species, with hairs sometimes spreading, sometimes reflexed. 100 Parry & Palmer (the same as 389 Botteri and 273 Bourgeau), referred to this species, is probably a stout large-leaved form of the next.

Geranium Mexicanum, HBK. (*G. Hernandezii*, Engelm. in Gray's Pl. Fendl. 27, not DC.) San Rafael Mountains (188 Schaffner). Resembling the last, but with the more divergent lobes of the small leaves less narrowly dissected, hairs reflexed, the pedicels, calyx, and beaks of the fruit glandular-pubescent, and the calyx usually smaller.

Geranium Hernandezii, DC. In the San Miguelito Mountains (191 Schaffner). Well marked by the deltoid 3-lobed leaves, the long middle lobe lanceolate.

Geranium Schiedeanum, Cham. & Schlecht., var. More or less sparingly strigose-pubescent, the flowers sometimes yellowish-white. At Lerios, Coahuila (137), and in the San Rafael, San Miguelito, and Escabrillos Mountains (186, 187, 189 Schaffner); 99 Parry & Palmer.

Geranium crenatum. Stems short from a branching rootstock, little exceeding the radical leaves, and with the petioles covered with soft spreading hairs: leaves appressed-pubescent, about an inch broad, reniform-orbicular, about 5-cleft to below the middle, the broad lobes shortly 3–5-cleft at the rounded summit and somewhat crenately toothed: peduncles elongated, 2–5-flowered: calyx and pedicels villous and glandular-pubescent, the sepals (3 or 4 lines long) very shortly cuspidate; petals rose-color, 8 lines long: fruit erect, an inch in length.—At Lerios, Coahuila (136). The leaves resemble in outline those of *G. molle* and *G. Pyrenaicum*.

Oxalis corniculata, Linn. At Lerios (133), Saltillo (134), and Soledad, Coahuila (135); San Luis Potosi (761 Schaffner, in part).

Oxalis Wrightii, Gray. At San Luis Potosi (761 Schaffner, with the last). Closely resembling *O. corniculata*, but distinguishable by the thick fusiform root and usually more deeply-cleft leaflets.

Oxalis dichondræfolia, Gray. At Guadalupe, Texas (138).

Oxalis decaphylla, HBK. In the San Miguelito Mountains (762 Schaffner); 102 Parry & Palmer.

Peganum Mexicanum, Gray. At Parras (150); 105 Parry & Palmer.

Thamnosma Texanum, Torr. At Monclova (141) and Monterey (140); 104 Parry & Palmer.

Astrophyllum dumosum, Torr. In the mountains east of Saltillo (139). The well-developed petals are oblong-lanceolate, 4 lines long, glandular-punctate, and white or yellowish.

Xanthoxylum Pterota, HBK. At Guajuco, Nuevo Leon (195).

Xanthoxylum Clava-Herculis, Linn., var. (*X. macrophyllum*, Nutt.) With the leaves all trifoliolate. West of San Antonio, Texas (2125).

Ptelea angustifolia, Benth. At Saltillo, in flower (145), and in the mountains east of that place, in fruit (146).

Ptelea trifoliata, Linn., var. mollis, Torr. & Gray. At Georgetown and Bluffton, Texas (147, 148).

Helietta parvifolia, Benth. in Hook. Icon. Pl. t. 1385. At Monterey (142) and in the mountains north of Monclova (143, 144). Previously collected at Monterey by Berlandier (144 and 1404), and referred to *Ptelea parvifolia*, Gray (Hemsl. Bot. Centr.-Amer. 1. 170), which species rests upon Dr. Gregg's specimens only, collected on the Buena Vista battle-field and east of Marin.

Casimiroa edulis, Llav. & Lex. At Guajuco (149).

Castela Nicholsoni, Hook. At Laredo, Texas (152), and at Juraz, Coahuila; 107 Parry & Palmer.

Kœberlinia spinosa, Zucc. At Eagle Pass and Laredo, Texas (151), and at San Luis Potosi (94 Schaffner); 106 Parry & Palmer.

Cedrela ——? The lanceolate leaves with a long attenuate acumination, and the flowers in a close cymose panicle. At Guanajuato (Dugès).

Ilex decidua, Walter. At Georgetown, Texas (153, 154).

Schæfferia cuneifolia, Gray. At Uvalde, Texas (155), and westward toward Laredo.

Pachystima Myrsinites, Raf. In the Sierra Madre, forty miles south of Saltillo; a few specimens apparently of this species, though without flowers or fruit.

Llavea integrifolia, Hemsl. At Guajuco, Nuevo Leon (182), and in the mountains north of Monclova, Coahuila (183).

Mortonia scabrella, Gray. At Parras, Coahuila (2111).

Mortonia Greggii, Gray. A variety with narrow leaves and glabrous or nearly so (*M. Palmeri*, Hemsl.). In the Sierra Madre south of Saltillo (323); also in the mountains east of Saltillo, very sparingly. 558 Gregg is the same, though more pubescent. *M. effusa*, Turcz., founded on 2119 Berlandier, must also be *M. Greggii*.

Zizyphus obtusifolius, Gray. A variety with small coriaceous glaucous leaves, from ovate to narrowly oblong, occasionally toothed, and the inflorescence very pubescent. At Eagle Pass, Texas (168), and at San Lorenzo de Laguna, Coahuila (166).

Zizyphus lycioides, Gray. At Lerios, Coahuila (167).

Condalia spathulata, Gray. At Eagle Pass, on the Rio Grande (160, 164), and at Saltillo (162); 111, and 112 in part, Parry & Palmer.

Condalia obovata, Hook. At San Antonio (161) and Uvalde, Texas (163).

Condalia Mexicana, Schlecht. In the Morales Mountains (93 Schaffner) and in San Luis Potosi Valley (1060 Schaffner); 112, in part, and 113 Parry & Palmer.

Microrhamnus ericoides, Gray. At Lerios (165).

Karwinskia Humboldtiana, Zucc. At Laredo, on the Rio Grande (173), and on Corpus Christi Bay.

Rhamnus Caroliniana, Walter. Kendall County, Texas (172).

Adolphia infesta, Meisn. At Guanajuato (Dugès). This is probably the *Colletia* (?) *multiflora* of De Candolle.

Colubrina glomerata, Hemsl. (*Barcena Guanajuatensis*, Dugès, Rev. Cient. Mex. 1. 8, t.) At Guanajuato (Dugès).

Colubrina Greggii. An erect shrub, the branches pubescent: leaves oblong-ovate to lanceolate, acute or acuminate, subcordate at base, finely and acutely serrate, more or less rufous-tomentose beneath, less pubescent above, 2 or 3 inches long: peduncles axillary, bearing 1 to 3 pedicellate globose (drupaceous) capsules, 3 or 4 lines in diameter: seeds dark brown, shining, with an obscure protuberance on the back. — At Soledad, Coahuila (171), and at Monterey, Nuevo Leon (154 Gregg). The fruit much resembles that of *C. Texensis;* the carpels separating to the base through the calyx and dehiscent to the middle, but with firmer walls; the seeds are less turgid and more shining.

Ceanothus azureus, Desf. (*C. cæruleus*, Lag.) Locality uncertain (176); 118 and 119 Parry & Palmer.

Ceanothus depressus, Benth. San Rafael Mountains (103 Schaffner); 122 Parry & Palmer, referred to *C. buxifolius*.

Ceanothus Greggii, Gray. A variety with the leaves white-tomentose beneath, and occasionally with a few spinose teeth. At Lerios, Coahuila (175). Also the typical form from the Morales Mountains (102 Schaffner); 120 Parry & Palmer.

Ampelopsis pubescens, Schlecht. At Guanajuato (Dugès).

Vitis incisa, Nutt. At Laredo, on the Rio Grande (177).

Vitis æstivalis, Michx. At Parras, Coahuila (180), and in the mountains near Saltillo (2126). — Also var. cinerea, Engelm. (?), with different seeds from those of the preceding. Southwestern Texas (178).

Vitis cordifolia, Michx., var. (?) Covered throughout with a very short spreading pubescence, the leaves less acuminate and more bluntly toothed than in the typical form. In the Caracol Mountains, southeast of Monclova, Coahuila (179).

Cardiospermum Halicacabum, Linn. At Uvalde (185) and at Sutherland Springs, Texas (366).

Cardiospermum molle, Linn. At San Luis Potosi (100 Schaffner); 123 Parry & Palmer.

Serjania (?) inflata. Branches herbaceous, elongated, puberulent, the tendrils often not floriferous: leaves like those of *Cardiospermum Halicacabum*, somewhat pubescent: flowers in a small racemose panicle, bicirrhose at base: petals 3 lines long: ovary about equalling the pubescent style; capsule an inch long or more, glabrous, thin-membranous, resembling that of *C. Halicacabum*, but abruptly rounded above, and the carpels attenuate downward and wing-margined below the middle: seed solitary in each cell, attached to the middle of the axis. — In the Caracol Mountains, Coahuila (186). Closely allied to *S. macrococca*, Radlk., and *S. incisa*, Torr. (*Paullinia subulata*, Gray), and intermediate between *Serjania* and *Cardiospermum*. It would perhaps be better to refer all these species to the latter genus.

Serjania brachycarpa, Gray. At Corpus Christi Bay (125).

Serjania racemosa, Schum. At Guanajuato (Dugès).

Ungnadia speciosa, Endl. At Saltillo, Coahuila (187), and at Guajuco, Nuevo Leon.

Sapindus marginatus, Willd. In Burnet County, Texas (184).

Acer grandidentatum, Nutt. In the Caracol Mountains, Coahuila, a single specimen of foliage only.

Negundo aceroides, Moench. At San Luis Potosi (88 Schaffner); "a very tall tree in cultivated places."

Dodonæa viscosa, Linn. At Monterey (127), and Guajuco, Nuevo Leon (181); San Luis Potosi (97 and 709 Schaffner); 96 Parry & Palmer.

Rhus Copallina, Linn., var. lanceolata, Gray. At Uvalde, and at Sutherland Springs, Texas (191).

Rhus microphylla, Engelm. At Sutherland Springs, Texas (193), at Saltillo, Coahuila (192), and in the San Miguelito Mountains (92 and 1061 Schaffner); 126 Parry & Palmer. A shrub 10 to 12 feet high, in the latter locality, popularly known as "Correosa."

Rhus pachyrrhachis, Hemsl. In the San Miguelito Mountains (95 and 908 Schaffner); 125 Parry & Palmer.

Rhus virens, Lindl. At Uvalde, Texas (188), in the Sierra Madre south of Saltillo (190), and in the Caracol Mountains, Coahuila (189).

Rhus Toxicodendron, Linn. At Uvalde, Texas (194); 124 Parry & Palmer.

Pistacia Mexicana, HBK. At Saltillo, Coahuila (196), and in the Morales, San Rafael and San Miguelito Mountains, San Luis Potosi (89, 90 and 91 Schaffner); 98 Parry & Palmer.

Crotalaria pumila, Ort. Near San Luis Potosi (814 Schaffner); 127 Parry & Palmer.

Crotalaria eriocarpa, Benth. In the same locality (813 Schaffner). 128 Parry & Palmer is the same, referred to *C. Maypurensis*, HBK., but the pod is densely tomentose-villous, instead of appressed silky-pubescent. 26 Ervendberg, referred to *C. anagyroides*, HBK., is rather *C. Maypurensis.*

Lupinus Ehrenbergii, Schlecht. At Lerios, Coahuilá (197), and near San Luis Potosi (801 Schaffner), 132 Parry & Palmer. This is also 61 Hartweg, in part.

Lupinus bilineatus, Benth. (*L. Hartwegi*, Lindl.) At Guanajuato (Dugès). Known as "Elotitos" or "Yerba de San Marcos."

Lupinus Leonensis. Biennial (?), branching at the base and the leafy stems decumbent (6 to 12 inches high), coarsely villous throughout, the hairs appressed or somewhat spreading: petioles about twice longer than the leaves; leaflets 5, oblanceolate, acute, very silky below and on the margin, glabrous or nearly so above, 6 to 10 lines long or less; stipules linear-subulate, elongated: flowers blue, 5 lines long, scattered in a short raceme, on slender pedicels 1 to 1½ lines long; bracts lanceolate, deciduous, shorter than the calyx: calyx-tube turbinate: pod linear, 4–6-seeded, 12 to 15 lines long by 3 broad. — At Guajuco, Nuevo Leon (198).

MELILOTUS PARVIFLORA, Desf. At San Lorenzo de Laguna, Coahuila (190).

MEDICAGO MINIMA, Lam. At Monterey, Nuevo Leon (200).

TRIFOLIUM AMABILE, HBK. At Morales, San Luis Potosi (806 Schaffner), a narrow-leaved form, the var. LONGIFOLIOLUM, Hemsl.; 134 Parry & Palmer.

TRIFOLIUM INVOLUCRATUM, Willd. In the mountains east of Saltillo, scanty specimens; at Morales (807 Schaffner); 135 Parry & Palmer.

TRIFOLIUM SCHIEDEANUM. (*T. reflexum*, Schlecht. in Linnæa, 5. 576.) Perennial, cespitose and procumbent, pubescent: leaflets from cuneate-obcordate to oblanceolate or rhombic-oblong, 3 to 8 lines long: peduncles axillary, exceeding the leaves: heads without involucre; flowers rather few, pedicellate, becoming reflexed, 3 lines long: calyx villous-pubescent, the very narrowly attenuate teeth twice longer than the tube; corolla not inflated in fruit. — Jalapa (Schiede), and at Lerios, 45 miles east of Saltillo (201). Allied to *T. elegans* and *T. hybridum*.

HOSACKIA ANGUSTIFOLIA, Don. In the Morales Mountains, San Luis Potosi (820 Schaffner); 140 Parry & Palmer.

HOSACKIA PUBERULA, Benth. Near San Luis Potosi, in sandy places (819 Schaffner); 141 Parry & Palmer.

PSORALEA RHOMBIFOLIA, Torr. & Gray. At Corpus Christi Bay, Texas (223), and at Monterey, Nuevo Leon (222). Also a nearly glabrous variety, with the heads of larger bracteate flowers more open and subracemose; in the Sierra Madre, Coahuila (254).

PSORALEA PENTAPHYLLA, Linn. Near San Luis Potosi, in sandy places (833 Schaffner); 142 Parry & Palmer. Known as "Contra-yerba."

EYSENHARDTIA AMORPHOIDES, HBK. At Uvalde (204) and Sutherland Springs, Texas (203), in the mountains west of Saltillo (202) and at Soledad, Coahuila (2114), also at Guanajuato (Dugès).

EYSENHARDTIA ORTHOCARPA. (*E. amorphoides*, var. *orthocarpa*, Gray, Pl Wright. 2. 37.) A tree, 10 to 15 feet high, distinguished from the last by the more numerous leaflets (10 to 23 pairs), and by the larger (5 to 8 lines long) straight pendent pods. — In New Mexico (98 and 116 Wright), Arizona (Pringle), near San Luis Potosi

(143 Parry & Palmer, 782 Schaffner); also 82 Bourgeau, 108 Bilimek, 15 and 230 Ervendberg, and collected by Seemann — all referred to the last species, which has 5 to 14 (usually 10) pairs of leaflets, and shorter (3 to 4 lines long) erect curved pods.

DALEA POGONATHERA, Gray. In Wilson County, Texas (221), at Monclova (216) and Soledad, Coahuila (220), and at Monterey, Nuevo Leon (219); 163 Parry & Palmer.

DALEA LASIATHERA, Gray. In the Caracol Mountains, Coahuila (225), and at Guajuco, Nuevo Leon (224).

DALEA TUBERCULATA, Lag. At Saltillo, Coahuila (2113), in the San Miguelito Mountains, with white flowers (784 Schaffner), and in the mountains near San Luis Potosi, with purple flowers (783 Schaffner); 156, 157, 158 Parry & Palmer.

DALEA TRIFOLIOLATA, Moric. (*D. triphylla*, Schlecht.) Near San Luis Potosi, in sandy places (795 Schaffner), and at Guanajuato (Dugès); 165 Parry & Palmer.

DALEA BERLANDIERI, Gray. In the Sierra Madre, south of Saltillo (209).

DALEA LASIOSTACHYS, Benth. Near San Luis Potosi, in shady woods (788 Schaffner); 149, 150, 155 Parry & Palmer.

DALEA LEUCOSTOMA, Schlecht. At Lerios, Coahuila, a single specimen, and near San Luis Potosi (789 Schaffner); 153 Parry & Palmer.

DALEA RAMOSISSIMA, Benth. In the San Miguelito Mountains (785 Schaffner); 154 Parry & Palmer.

DALEA ALOPECUROIDES, Willd. Near San Luis Potosi (791 and 1058 Schaffner), and at Guanajuato (Dugès); 144 Parry & Palmer.

DALEA PECTINATA, Benth. Near San Luis Potosi (790 Schaffner); 146 Parry & Palmer.

DALEA CITRIODORA, Willd. Near San Luis Potosi (792 Schaffner); 145 Parry & Palmer.

DALEA AUREA, Nutt. In the Caracol Mountains, Coahuila (226); a variety with the bracts more acuminate than in the typical form.

DALEA NANA, Torr. In the Sierra Madre, south of Saltillo (228), at Monclova (227), and at Soledad, Coahuila (217), and at Monterey, Nuevo Leon (218).

DALEA ERIOPHYLLA. Dwarf (6 inches high), frutescent, repeatedly branched and very leafy, covered throughout with a dense fine white tomentum: leaves trifoliolate, the oblong leaflets about a line long; petioles short: flowers in small dense terminal sessile heads: calyx very densely white silky-villous, $1\frac{1}{2}$ lines long, the lanceolate acuminate teeth as long as the tube; corolla rose-color, 3 lines long. — In the Sierra Madre, forty miles south of Saltillo (211). Allied to *D. Greggii.*

Dalea polycephala, Benth. In the same locality (208), also in the Escobrillos and San Rafael Mountains, San Luis Potosi (786 and 787 Schaffner); 160 Parry & Palmer.

Dalea Wrightii, Gray. In the Caracol Mountains, Coahuila (229); 162 Parry & Palmer.

Dalea Luisana. Perennial, herbaceous, the slender sparingly branched stems decumbent or ascending (2 to 6 inches long), covered throughout with an appressed silky pubescence: leaves few, trifoliolate: leaflets about equalling the petioles, linear-oblong, obtuse or acutish, glabrous above or nearly so, 3 to 9 lines long by 1 or $1\frac{1}{2}$ wide: flowers in close sessile heads (the rhachis at length 3 to 9 lines long); bracts silky, ovate, acuminate, equalling the very villous calyx: calyx-teeth filiform, bearded, exceeding the tube and equalling the yellow corolla (2 or nearly 3 lines long). — In the San Miguelito Mountains (808 Schaffner); it is also 164 Parry & Palmer, referred to *D. Wrightii.*

Dalea Greggii, Gray. At Monterey, Nuevo Leon (213); 147, 152 Parry & Palmer, and 1048, in part. 148 Parry & Palmer, with a part of 1048, referred to *D. pulchella*, is some other unrecognized species.

Dalea mollis, Benth. In the mountains north of Monclova (215); 161 Parry & Palmer.

Dalea frutescens, Gray. In Wilson County, Texas (207), in the Sierra Madre, south of Saltillo (206), and at Juraz, Coahuila (205), and at Monterey, Nuevo Leon (212). Also a variety with elongated loosely flowered spikes, the calyx slightly more pubescent, and the larger petals 4 to 6 lines long, changing from creamy white to pale rose-color: in the Caracol Mountains, Coahuila (210).

Dalea radicans. Frutescent, glabrous, much branched, the slender stems short and erect or elongated and trailing and occasionally rooting: leaves half an inch long or less, the leaflets (6 to 9 pairs) very narrowly linear, obtuse, 1 or 2 lines long: spike nearly sessile, open, few- (rarely 10-) flowered: calyx as in *D. frutescens*, villous in the throat, but the triangular teeth longer and more acuminate, half the length of the tube; corolla 3 lines long, magenta. — In the Sierra Madre, south of Saltillo (214). Nearly allied to *D. frutescens.*

Petalostemon obovatus, Torr. & Gray. Near San Antonio, Texas (230).

INDIGOFERA LINDHEIMERIANA, Scheele. At Uvalde, Texas (232), and in the mountains north of Monclova, Coahuila (233).

INDIGOFERA LEPTOSEPALA, Nutt. Near San Antonio (231), and in Wilson County, Texas (253). This is also 20 and 27 Ervendberg, referred to *I. subulata*. — Var. BREVIPES. With short peduncles not exceeding the leaves, and very short few-flowered racemes scarcely elongated in fruit, and the petals but little longer than the calyx-lobes; leaflets as in the typical form, 3 to 9, oblong-obovate to oblanceolate, pubescent on both sides. In the San Rafael Mountains (818 Schaffner); 138 and 139 Parry & Palmer. — Var. (?) ANGUSTATA. Resembling the last variety in the shortness of the peduncle, but the leaflets narrower and more numerous (5 to 16), mostly linear, acute or obtuse, glabrous above. Near Morales (817 Schaffner).

BRONGNIARTIA INTERMEDIA, Moric. In the San Miguelito Mountains (828 Schaffner).

PETERIA SCOPARIA, Gray, var. GLANDULOSA, Gray, in herb. Low (6 to 12 inches high or less), from a thick tuberous root, with numerous spreading branches, and the inflorescence very viscid pubescent (as in *P. Thompsonæ*): leaves 6 to 12 lines long: seeds numerous and more turgid. — Near San Luis Potosi (834 Schaffner); 172 Parry & Palmer. Probably distinct. The root is esculent, and known under the name of "Camote del monte."

TEPHROSIA TENELLA, Gray (?) At Soledad, Coahuila (257). Closely resembling this species, except that it appears to be perennial, the several herbaceous stems arising from a rather thick rootstock.

TEPHROSIA LINDHEIMERI, Gray. At Laredo, on the Rio Grande (258).

SESBANIA MACROCARPA, Muhl. At San Antonio (278, mainly).

SESBANIA CAVANILLESII, Watson. (*Daubentonia longifolia*, DC.) At San Antonio, Texas — fruit only, distributed with the last. 209 Parry & Palmer belongs to this species, not to *S. longifolia*, DC., which according to the description is very different.

ASTRAGALUS HUMBOLDTII, Gray. At Lerios (240), at Parras (242), and in the Sierra Madre, south of Saltillo (241), the latter with somewhat shorter calyx-teeth; 170 and 171 Parry & Palmer.

ASTRAGALUS ORTHANTHUS, Gray. In the Sierra Madre, south of Saltillo (243, 2137).

ASTRAGALUS BRAZOENSIS, Buckl. Between the Rio Frio and the Nueces, Texas (244).

ASTRAGALUS DIPHACUS. Biennial or perennial, canescently puberulent: stipules distinct, lanceolate; leaves 2 to 4 inches long; leaflets

6 to 12 pairs, linear to narrowly oblong-lanceolate, obtuse, glabrous above, 3 to 8 lines long: racemes short and dense, 1 or 2 inches long in fruit, or less, on elongated peduncles: calyx campanulate, 2 lines long, the narrowly acuminate teeth little shorter than the tube; corolla whitish, 3 or 4 lines long: pod coriaceous, sessile, 2-celled, compressed-subglobose and somewhat didymous, 3 or 4 lines long, slightly pubescent, at length reticulately veined. — In the San Miguelito Mountains (816 Schaffner, mainly).

Astragalus Hartwegi, Benth. (*A. vaccarum*, Gray.) At San Lorenzo de Laguna, Coahuila (235).

Astragalus Nuttallianus, DC. At Monterey (237).

Astragalus leptocarpus, Torr. & Gray. At Monterey, a single specimen, and near San Luis Potosi (822 Schaffner); 176 Parry & Palmer.

Astragalus Arizonicus, Gray. At Parras, Coahuila (234). Stems more erect than usual.

Astragalus Greggii. Apparently biennial or perennial, the slender stems ½ to 1 foot long or more, densely pubescent with white spreading or reflexed hairs: stipules triangular, surrounding the stem; leaves 1 to 1½ inches long; leaflets 4 to 8 pairs, obovate to oblong, obtuse or truncate or retuse, tomentose-pubescent or nearly glabrous, 1 to 3 lines long: peduncles elongated, tomentose; raceme loosely few-flowered: calyx tomentose, the long-acuminate teeth exceeding the short campanulate tube; corolla 4 lines long, red and white: pod chartaceous, completely 2-celled by the intrusion of the dorsal suture, sessile, ascending or spreading, linear-oblong, compressed, slightly curved, glabrous, 6 to 9 lines long. — In the mountains east of Saltillo (238); also collected by Gregg (439), the locality not stated.

Astragalus strigulosus, HBK., var. gracilis, Hemsl. In the San Miguelito Mountains (821 Schaffner); 175 Parry & Palmer.

Astragalus parvus, Hemsl. Much larger specimens than the original, the ascending or erect stems a foot high or less; leaflets linear to linear-oblong, 2 to 6 lines long. In the San Miguelito Mountains (815 Schaffner); 174 Parry & Palmer.

Astragalus triflorus, Gray. In the San Miguelito Mountains (816 Schaffner, in part); 173 Parry & Palmer.

Astragalus Antoninus. Biennial, canescent with short appressed pubescence, the slender ascending stems flexuous, ½ to 1 foot high: leaves 2 or 3 inches long; leaflets 6 to 9 pairs, linear to narrowly oblong, obtuse, 4 to 6 lines long: peduncles elongated; racemes open, few-flowered: calyx pubescent, tubular-campanulate, 3 lines long, the short acuminate teeth hardly half the length of the tube; corolla rose-color, 6 lines long: pod ascending, coriaceous, oblong-ovate and turgid, abruptly contracted to a very short stipe, 1-celled, with neither suture intruded or the dorsal slightly impressed, about 8 lines long, straight, subpubescent. — In the Sierra Madre, south of Saltillo (239), and also collected by Dr. Gregg (363) at San Antonio de las Alanganes. It belongs to the group *Scytocarpi*, and is apparently allied to *A. coriaceus*, Hemsl.

NISSOLIA WISLIZENI, Gray. In the San Miguelito and San Rafael Mountains (793 and 794 Schaffner).

NISSOLIA PLATYCALYX. Somewhat tomentose-pubescent: leaflets 2 or 3 pairs, oblong to oblong-obovate, obtuse or retuse, mucronate, 3 to 6 lines long: calyx-tube broadly campanulate, 2 to 2½ lines long, the filiform teeth nearly as long; corolla greenish yellow, 8 lines long, the standard pubescent: ovary glabrous at base, finely pubescent above: fruit glabrous or nearly so, 1–3-jointed, 1 to 1½ inches long, the joints rather strongly 3-costate on each side, the upper one with a curved wing 9 to 12 lines long by 5 or 6 lines broad, thickened on the dorsal edge. — In the mountains east of Saltillo (248, in part). Under the same number were distributed specimens of another unrecognized species, with the round-elliptical to ovate leaflets less pubescent, as well as the petioles, the calyx-tube only a line long, and the ovary and fruit pubescent and villous with scattered yellow hairs.

STYLOSANTHES MUCRONATA, Willd. In the San Miguelito Mountains (800 Schaffner). Agreeing closely with this East Indian species, which differs from *S. procumbens*, Sw., in its pubescence, and in the form and size of the pod.

ZORNIA TETRAPHYLLA, Michx. Wilson County, Texas (245).

ZORNIA DIPHYLLA, Pers. At San Luis Potosi (805 Schaffner); 196 Parry & Palmer.

DESMODIUM VIRIDIFLORUM, Beck. In the Caracol Mountains, Coahuila (246).

DESMODIUM PSILOPHYLLUM, Schlecht. In the same locality (2136), a variety with broader leaves (4 to 6 lines wide) and verging towards *D. Wrightii*, Gray, which is very variable in its foliage, and apparently to be united with the present species.

DESMODIUM PALMERI, Hemsl. Near San Luis Potosi (796 Schaffner, in part); 179 Parry & Palmer, mixed with *D. Parryi* in the Gray Herbarium set.

DESMODIUM SPIRALE, DC. Same locality (796 Schaffner, in part); 181 Parry & Palmer.

Desmodium Wislizeni, Engelm. With the preceding and distributed under the same number; the same as 180 Parry & Palmer. Differing from *D. spirale* in its perennial root and more or less abundant spreading pubescence.

Desmodium Parryi, Hemsl. In the San Miguelito Mountains (797 Schaffner, in part); 178 Parry & Palmer.

Desmodium gracile, Mart. & Gal. (?) With the last (797 Schaffner, in part). Flowering specimens, which agree fairly with the description.

Desmodium molliculum, DC. At San Rafael, in woods (798 Schaffner). Leaves varying from orbicular to ovate, and from half an inch to over 2 inches long.

Desmodium orbiculare, Schlecht. In the San Miguelito Mountains (799 Schaffner); 177 Parry & Palmer.

Lespedeza repens, Barton. At Sutherland Springs, Texas (250), and in the Caracol Mountains, Coahuila (249).

Vicia Americana, Linn., var. linearis, Watson. In the Caracol Mountains (247).

Vicia pulchella, HBK. At Lerios, Coahuila (2135), and in the San Rafael Mountains (823 Schaffner).

Lathyrus parvifolius. Glabrous throughout; stem rather stout, tall, not winged: stipules more or less broadly semisagittate; petiole tendril-bearing; leaflets 4 to 6 pairs, rhombic-oblong to ovate, acute, 6 to 12 lines long: peduncles exceeding the leaves, loosely 6–12-flowered: calyx-teeth triangular, much shorter than the tube; corolla purple, 6 to 8 lines long: pod sessile, linear, 2 inches long by about 3 lines broad. — In the San Miguelito Mountains, San Luis Potosi (812 Schaffner); 197 Parry & Palmer, referred to *L. venosus*.

Cologania humifusa, Hemsl. In the San Miguelito Mountains (803 Schaffner); 194 Parry & Palmer.

Cologania longifolia, Gray. At Lerios, Coahuila (251). The same as 189 Parry & Palmer, referred to *C. angustifolia*, from which it is distinguished only by the closely appressed pubescence and straight pod.

Cologania pulchella, HBK. In the San Miguelito Mountains (804 Schaffner); 192 Parry & Palmer.

Cologania Martia. Stems very slender, from a thick rootstock, trailing, a foot long or less, retrorsely strigose-pubescent: leaflets oblong (4 to 12 lines long by 2 to 4 wide), or the lower oblong-obovate or elliptical, glabrous above and strigose beneath, usually very obtuse or retuse: flowers purple, an inch long or more, on rather long pedicels (3 to 15 lines), solitary or in pairs in the axils; calyx appressed-pubescent, half an inch long: pod nearly straight, an inch long. — In sandy places about San Luis Potosi (802 Schaffner). It is also 191 and 193 Parry & Palmer, the former number representing the cleistogamous form upon which Zuccarini founded the genus *Martia*. In this the flowers are nearly sessile, the petals wanting, and the calyx very much reduced.

Erythrina coralloides, DC. In mountains near San Luis Potosi (96 Schaffner). Known as "Colorin."

Apios tuberosa, Moench. At Sutherland Springs, Texas (2134).

Galactia brachystachys, Benth. At Saltillo, Coahuila (252).

Galactia marginalis, Benth. At Corpus Christi Bay, Texas; scanty specimens. The tuberous roots are said to be much relished as food.

Canavalia villosa, Benth. In the Caracol Mountains, south of Monclova (259).

Phaseolus atropurpureus, DC. In the mountains north of Monclova (262).

Phaseolus diversifolius, Pers. At Laredo, Texas (263).

Phaseolus retusus, Benth. Near San Luis Potosi, in sandy places (825 Schaffner); 185 Parry & Palmer. The root is described as tuberous, and the stems prostrate, 15 to 20 feet long.

Phaseolus heterophyllus, Willd. In the same locality (811 Schaffner, in part); 187 Parry & Palmer.

Phaseolus (Drepanospron) polymorphus. Stems from an esculent tuberous root, 3 feet long or more, glabrous or nearly so: leaves (usually ½ to 1 inch long, sometimes 2 or 3 inches long) hastately lobed (the lower rarely ovate), the terminal lobe from short-triangular (or sometimes obsolete) to oblong or linear, acute, the lateral short or elongated, obtuse or truncate or acute: peduncles exceeding the leaves, few-flowered: bracts small; bractlets firm and persistent, ovate, nerved, a little shorter than the calyx; pedicels 1 or 2 lines long: petals greenish white, 3 or 4 lines long: pod 1½ inches long by 4 lines broad, 2–4-seeded. — About San Luis Potosi (811 Schaffner, mainly); also 186 and 188 Parry & Palmer. Much resembling *P. filiformis*, Benth., which is an annual, with smaller calyx and bractlets, and much smaller pods. It is similar also to *P. Wrightii*, Gray, which has, however, very narrow thin and deciduous bractlets.

Phaseolus (Drepanospron) scabrellus, Benth. in herb. Gray. Stem and petioles pubescent: stipules triangular; leaves 1 to 1½ inches long, scabrous above, more or less hastate (or sometimes deltoid-ovate), truncate at base, acute, the middle lobe triangular to oblong, the basal rounded to quadrate: peduncles exceeding the leaves and with the inflorescence nearly glabrous; raceme open, the very slender pedicels 3 to 6 lines long; bracts and bractlets very small: corolla purplish, 5 or 6 lines long: ovary densely silky-pubescent; pod falcate, 1½ inches long by 4 lines wide. — In the Caracol Mountains, Coahuila (2122); also collected by Coulter in Sonora Alta (without number in herb. Gray).

PHASEOLUS MULTIFLORUS, Willd. (?) In the San Miguelito Mountains (824 Schaffner). Flowers scarlet; known as "Frijol del monte."

PHASEOLUS ——— ? At Soledad, Coahuila (261). Probably an undescribed species.

RHYNCHOSIA TEXANA, Torr. & Gray. At Lerios, Coahuila (256), and in the San Miguelito Mountains (835 Schaffner); 190 Parry & Palmer. This species has been referred to the South American *R. Senna*, but the reason is not apparent.

RHYNCHOSIA MINIMA, DC. At San Antonio, Texas (260).

RHYNCHOSIA MACROCARPA, Benth. In the San Miguelito Mountains (826 Schaffner); 184 Parry & Palmer.

RHYNCHOSIA PHASEOLOIDES, DC. In the Santa Maria del Rio Mountains (827 Schaffner).

SOPHORA SERICEA, Nutt. At Lerios, Coahuila (264); 199 Parry & Palmer.

SOPHORA SECUNDIFLORA, Lag. At Uvalde, Texas (266), and at Monterey, Nuevo Leon (265), and a form, densely white-silky throughout, at Parras, Coahuila (2133); 200 Parry & Palmer.

CÆSALPINIA MEXICANA, Gray. At Monterey (282); 1054 Parry & Palmer. *C. exostemma*, DC., is very similar, but has a firmer calyx with broader lobes, and stamens nearly twice longer than the corolla.

HOFFMANSEGGIA STRICTA, Benth. At Saltillo (267) and Parras, Coahuila (268), and near San Luis Potosi (832 Schaffner); 202 Parry & Palmer. The tuberous roots are edible, and known as "Camote del raton."

HOFFMANSEGGIA GRACILIS. Herbaceous, low (about 4 inches high), very slender, puberulent but not glandular nor villous: pinnæ 1 to 3 pairs, with an odd one; leaflets 5 to 8 pairs, oblong, about 2 lines long, nearly glabrous: raceme loosely flowered: calyx finely puberulent: pod linear-oblong, very acute, slightly curved, 9 to 12 lines long by about 2 lines broad, 6–9-seeded. — In the Sierra Madre, south of Saltillo (275). Allied to *H. oxycarpa*.

Parkinsonia Texana, Watson. At Uvalde (270), and Eagle Pass, Texas (271).

Parkinsonia aculeata, Linn. At San Antonio, Texas (272); 203 Parry & Palmer.

Cassia leptocarpa, Benth. Near San Luis Potosi (830 Schaffner), and at Guanajuato (Dugès); 204 Parry & Palmer.

Cassia Rœmeriana, Scheele. At Sutherland Springs (280).

Cassia pumilio, Gray. At Laredo, on the Rio Grande (273); 210 Parry & Palmer.

Cassia bauhinioides, Gray. At Monclova, Coahuila (274), and at San Luis Potosi (831 Schaffner); 206 Parry & Palmer. Also a villous and densely silky variety, with longer slender style, and the rather straighter pod with a longer beak; at San Lorenzo de Laguna (2134); 244 Gregg, from Saltillo, is the same.

Cassia Lindheimeriana, Scheele. At San Antonio (276).

Cassia occidentalis, Linn. At San Antonio (277), and at Guanajuato (Dugès), where it is known as "Bricho."

Cassia Vogeliana, Schlecht. In the Sierra Madre, south of Saltillo (281).

Cassia Wislizeni, Gray (?) Leaflets oblong-obovate, acute, 3 to 6 lines long: pods 4 to 6 inches long. In the Morales Mountains (829 Schaffner). Also from hills near Presidio, W. Texas (Dr. V. Havard), with the leaflets smaller but acute.

Cassia Greggii, Gray. At Soledad, in flower and in fruit (283).

Cassia Chamæcrista, Linn. At Sutherland Springs (279).

Bauhinia ramosissima, Benth. (?) At Monclova, Coahuila (285). Differing from Coulter's specimen, as described by Hemsley, in having its flowers only half as large and the ovary glabrous.

Cercis reniformis, Engelm. (*C. occidentalis*, Torr., var. *Texensis*, Watson.) In the Caracol Mountains, south of Monclova.

Prosopis cinerascens, Gray. Between the Rio Frio and Nueces, Texas (286), and at Juraz, Coahuila.

Prosopis juliflora, DC. At Eagle Pass, Texas (288), at Parras, Coahuila (287), and in the mountains near San Luis Potosi (629 Schaffner); 211 Parry & Palmer.

Neptunia pubescens, Benth. At Juraz, Coahuila (300), and at Corpus Christi Bay, Texas.

Desmanthus velutinus, Scheele. At Eagle Pass, Texas (315).

Desmanthus depressus, Humb. & Bonpl. At San Antonio and Laredo, Texas (316), and at Monclova, Coahuila (317).

Desmanthus reticulatus, Benth. At Sutherland Springs, Texas.

Desmanthus incurvus, Benth. At Parras, Coahuila (314), and in the Sierra Madre south of Saltillo. This is also 201 Parry & Palmer, referred to *D. depressus*.*

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* The North American species of *Desmanthus* may be grouped and distinguished as follows: —

* Stamens 5. — Glabrous or nearly so: pinnæ 2 to 8 (usually 5) pairs, on a rhachis ½ to 3 inches long; leaflets linear: pod not attenuate at base.

1. D. brachylobus, Benth. Stout: heads many-flowered: peduncles 1 to 3 inches long: pod oblong, 2 or 3 lines broad, falcate. — Illinois and Florida to Texas and New Mexico.

2. D. leptolobus, Torr. & Gray. Slender: heads small: peduncles ½ to 1 inch long: pod elongated linear, a line broad, straight, acuminate. — Arkansas and Texas.

* * Stamens 10. — Pod linear: leaflets oblong.

+ Pinnæ 2 to 6 (usually 4 or 5) pairs on a rhachis ½ to 1½ inches long; leaflets veinless.

++ Heads many-flowered, on short peduncles.

3. D. Jamesii, Torr. & Gray. Rather stout, glabrous, or slightly pubescent and the leaflets ciliate: peduncles usually approximate at the summit, occasionally in pairs: pod 1½ to 3 inches long by 1½ or 2 lines broad, acuminate, obtuse or but slightly narrowed at base. — S. Colorado and W. Texas to Arizona.

++ ++ Heads smaller, on peduncles 1 to 2½ inches long: pubescent or rarely nearly glabrous.

4. D. velutinus, Scheele. Pod 1 to 2½ inches long by 1 or 1½ lines broad, acuminate, attenuate at base, straight or nearly so. — Texas.

5. D. incurvus, Benth. Pod 8 to 20 lines long by 2½ or 3 broad, acuminate, rounded or scarcely narrowed at base. — Mexico.

+ + Pinnæ 1 to 4 pairs: heads small.

++ Peduncles short (½ to 1 inch long): rhachis short (½ inch or less); pinnæ usually 1 or 2 pairs; leaflets veinless: pod 1 to 2½ inches long, acuminate, attenuate at base. — Species scarcely distinct.

6. D. depressus, Humb. & Bonpl. Usually glabrous, low and depressed, very slender: leaflets small and narrow: pod straight or nearly so. — Florida to Texas, Mexico, etc.

7. D. virgatus, Willd. Stouter and more erect: leaflets mostly larger and broader. — Florida, W. Indies and S. America.

8. D. acuminatus, Benth. More pubescent: peduncles rarely over ½ inch long: pod 10 to 20 lines long, more or less curved. — Texas.

++ ++ Peduncles elongated (1 to 4 inches): leaflets veined: pod 1 to 1½ inches long, obtuse or slightly narrowed at base.

9. D. reticulatus, Benth. Glabrous or nearly so: rhachis ½ to 1½ inches long: peduncles usually 3 or 4 inches long: pod acuminate. — Texas.

10. D. obtusus, Watson. Pubescent: rhachis usually very short (½ inch or less): peduncles 1 to 2½ inches long: pod obtuse, apiculate. — W. Texas. (See p. 371.)

Mimosa malacophylla, Gray. At Monclova, Coahuila (299).

Mimosa monancistra, Benth. At Soledad, Coahuila (290).

Mimosa zygophylla, Benth. At Parras (296), and in the mountains east of Saltillo, Coahuila (297).

Mimosa acanthocarpa, Benth. In the mountains near San Luis Potosi (624 Schaffner, and 625 in part). This is the same as 217 Parry & Palmer (which is described by Hemsley as *M. flexuosa*, Benth.), with better developed and mostly larger leaves and leaflets. *M. flexuosa*, aside from its slender flexuous branches, differs in having its mature pods narrower (less than 2 lines broad) and armed with straighter spines.

Mimosa biuncifera, Benth., var. (?) In the mountains about San Luis Potosi (623 Schaffner); 216 Parry & Palmer, so referred by Hemsley. They also closely approach *M. Lindheimeri*.

Mimosa Lindheimeri, Gray, var. (?) The leaves with 1 to 3 pinnæ and few leaflets, as in 1363 Wright. At Uvalde, Texas (291), and at Saltillo, Coahuila, in flower (295). Also a variety with few but larger pinnæ and more numerous leaflets, and the broad pods obtuse; at Parras (292), and in the mountains east of Saltillo, in flower (293, 294).

Mimosa ——? At Parras were collected flowering specimens of another species of this group, with old fruit, but the foliage imperfectly developed. Pubescent, with small curved spines mostly in pairs: pinnæ 2 to 4 pairs, with 4 to 6 pairs of small leaflets: pod coriaceous, unarmed, pubescent, straight, $\frac{1}{2}$ to 1 inch long by 2 lines broad.

Mimosa strigillosa, Torr. & Gray. At Juraz, Coahuila (2115).

Schrankia aculeata, Willd., var. (?) In the Sierra Madre south of Saltillo (301), and sparingly at Soledad, Coahuila, and at Sutherland Springs, Texas. Identical with 2513 Berlandier, so named by Bentham, but with the pod densely pubescent. The pod is long-beaked, instead of acute as described and figured from the original Vera Cruz specimens upon which the species was founded.

Schrankia subinermis. Glabrous, unarmed excepting the pod: pinnæ a single pair upon a petiole about an inch long; leaflets 6 to 10 pairs, oblong, veinless, slightly pubescent: peduncle 6 to 18 lines long: pod 2 inches long, beaked, glabrous, naked or very sparingly armed with short spines, chiefly on the margins. — In the mountains north of Monclova (302).

Leucæna glauca, Benth. At Saltillo (307)

Acacia Palmeri. A stout shrub, glabrous or nearly so, with short stout curved infrastipular and occasional scattered spines:

pinnæ 1 or rarely 2 pairs upon a rhachis 2 to 12 lines long; leaflets 2 to 5 pairs, oblong to oblong-obovate, 3 to 4 lines long: peduncles fascicled, an inch long: calyx glabrous, 1 to nearly 2 lines long, exceeding the narrow deciduous bractlet: ovary glabrous, stipitate. — In the Sierra Madre south of Saltillo (298). Allied to *A. Rœmeriana* and *A. micrantha*.

ACACIA FLEXICAULIS, Benth. At Corpus Christi Bay, Texas (305). Pinnæ always 2 pairs: spikes longer than in the next species and pedunculate: pod sessile upon a much-thickened branch-like peduncle.

ACACIA AMENTACEA, DC. Between the Rio Frio and Nueces, Texas (304); 213 Parry & Palmer. Pinnæ a single pair: spikes short and sessile: pod 2 or 3 inches long by 2 lines wide, attenuate into a stipe: spines very variable, sometimes short, often 1 to 2 inches long or more. Young fruit has recently been collected for the first time by Dr. V. Havard, U.S.A., and Dr. S. B. Buckley. This is said to be the most common species in Southwestern Texas, and to grow to a height of twenty feet.

ACACIA WRIGHTII, Benth. At Uvalde, Texas (303).

ACACIA BERLANDIERI, Benth. At Eagle Pass, Texas (2127), at Monterey, Nuevo Leon (308), and in the mountains east of Saltillo (309). A variety was collected at Eagle Pass (2127, in part) with narrower pods (6 to 8 lines wide) and smaller seeds (3 or 4 lines long). The ordinary form has the pod 9 to 14 lines broad and the seeds 5 or 6 lines long.

ACACIA CONSTRICTA, Benth. At Parras, Coahuila (313), and in the mountains near Los Pogos (627 Schaffner); 214 Parry & Palmer.

ACACIA FILICINA, Willd. At Parras (311), Juraz (310), and in the Caracol Mountains, Coahuila (2128), and at Sutherland Springs, Texas; 218 Parry & Palmer.

ACACIA FARNESIANA, Willd. In the Sierra Madre south of Saltillo (312). Known by the Mexicans as "Huisache."

ACACIA CRASSIFOLIA, Gray. At San Lorenzo de Laguna, Coahuila (284). The pod is very thick and coriaceous, 3 inches long by 8 lines broad, nearly annular and shortly stipitate

CALLIANDRA CONFERTA, Benth., but with slender peduncles. In the mountains east of Saltillo (318), and in the Morales Mountains (626 Schaffner).

CALLIANDRA ERIOPHYLLA, Benth., but with the fruiting peduncles short. At Saltillo, sparingly collected; the same as 212 Parry &

Palmer, referred to *C. conferta.* It appears most probable, however, that the two species cannot be kept distinct.

CALLIANDRA COULTERI. Stems herbaceous, very slender, glabrous, about a foot long: stipules herbaceous, lanceolate, 2 lines long; pinnæ 1 or 2 pairs on a rhachis ½ to 1½ inches long; leaflets 6 to 10 pairs, oblong, 2 to 4 lines long: peduncles 1 or 2 inches long: flowers sessile; calyx and corolla glabrous, short; stamens pink: pod glabrous, 1½ inches long. — At Soledad (2129); collected also by Coulter, without number or locality.

PITHECOLOBIUM PALMERI, Hemsl. In the San Miguelito Mountains (625 Schaffner, in part); 220 Parry & Palmer. The pod is stipitate, 3 or 4 inches long or more.

PITHECOLOBIUM BREVIFOLIUM, Benth. In the mountains north of Monclova (306).

PITHECOLOBIUM (CHLOROLEUCON) ELACHISTOPHYLLUM, Gray, in herb. A rigid much-branched shrub, armed with numerous short rather slender and somewhat curved spines, glabrous: pinnæ a single pair upon a petiole 1 or 2 lines long; leaflets 2 to 4 pairs, oblong-obovate, reticulated, 1 or 2 lines long: peduncles axillary, solitary, a line long, longer and much thickened in fruit; heads globose, rather open: flowers 2 lines long, the very numerous filaments 4 or 5 lines long, united into a slender tube: pod thick-coriaceous, 2 inches long by nearly ½ inch wide, stipitate. — At Monterey, Nuevo Leon (289).

PITHECOLOBIUM (CHLOROLEUCON) SCHAFFNERI. A stout shrub, armed with infrastipulary pairs of short stout straight spines, finely pubescent: pinnæ 2 to 4 pairs on a rhachis 3 to 10 lines long, with a round gland at the base of the upper and lower pairs; leaflets 10 to 15 pairs, oblong, acute, 1 to 1½ lines long: peduncles solitary, slender, ½ to 1 inch long: heads dense, globose, nearly glabrous: filaments numerous, united at base, 4 lines long: pod linear, straight or somewhat curved, 3 to 5 inches long by 4 or 5 lines wide, densely pubescent, flattened, thick and indehiscent, with a resinous endocarp and spongy septa between the seeds. — In the mountains about San Luis Potosi (628 Schaffner, and 623 in part); 219 Parry & Palmer, referred by Hemsley to *Acacia*, the flowers being unknown.

PRUNUS CAPULI, Cav. At Sutherland Springs, Texas (319^2), in the Sierra Madre south of Saltillo (320), in the mountains about San Luis Potosi (106 Schaffner), and at Guanajuato (Dugès); 222 Parry & Palmer. Popularly known as "Capulin."

PRUNUS GLANDULOSA, Torr. & Gray. In the Sierra Madre south of Saltillo (2131).

PRUNUS MEXICANA. Young branches, pedicels and petioles canescent with a short dense subtomentose pubescence: leaves deciduous, oblong-lanceolate or lanceolate, acuminate, rounded at base, acutely toothed, pubescent and lighter-colored beneath, puberulent above, 2 or 3 inches long: pedicels short, fascicled: fruit compressed-ovate, the very thick turgid stone 7 or 8 lines long, rounded on the margins, acutish. — At Lerios, Coahuila (2130).

SPIRÆA DISCOLOR, Pursh, var. DUMOSA, Watson. In the San Rafael Mountains (104 Schaffner); 223 Parry & Palmer.

VAUQUELINIA CORYMBOSA, Corr. In the Sierra Madre south of Saltillo (329).

LINDLEYA MESPILOIDES, HBK. In the same region (324).

RUBUS TRIVIALIS, Michx. (*R. humistratus*, Steud.) In the mountains about San Luis Potosi (105 Schaffner), the stem described as 20 to 30 feet long; 224 Parry & Palmer. The species is very variable in the amount of pubescence.

CERCOCARPUS PARVIFOLIUS, Nutt. At Lerios, Coahuila (174). Also var. PAUCIDENTATUS, with the small leaves entire or sparingly toothed at the summit, often densely pubescent; in shady places near San Miguelito (114 Schaffner). This is the same as 224 Parry & Palmer, and 1056 Wright. The typical form has occasionally a similar pubescence.

COWANIA PLICATA, Don. In the Sierra Madre south of Saltillo (325); 226 Parry & Palmer.

COWANIA MEXICANA, Don. At Guanajuato (Dugès).

FRAGARIA MEXICANA, Schlecht. At Lerios, Coahuila (326).

POTENTILLA HEPTAPHYLLA, Mill. In the Caracol Mountains, Coahuila (327).

POTENTILLA NORVEGICA, Linn. At San Lorenzo de Laguna, Coahuila (328); a form with the leaflets frequently divided.

ALCHEMILLA SIBBALDIÆFOLIA, HBK. In the Morales Mountains (868 Schaffner); 227 Parry & Palmer.

ALCHEMILLA HIRSUTA, HBK., var. ALPESTRIS, Schlecht. Villous with long scattered and spreading silky hairs, the leaves alike on both sides, and the calyx wholly glabrous. In the San Miguelito Mountains (869 Schaffner). This variety, and the more typical form (var. *campestris*, Schlecht., having the hairs appressed and more numerous, especially on the under side of the leaves, on the stem and calyx), have been distributed together under 721 Parry & Palmer, 71 Coulter (referred to *A. tripartita*), and 82 Ghiesbreght. 308[3] Bourgeau, also referred to *A. tripartita*, is the present variety. The lobes of the leaves vary greatly in their division, from incisely toothed to very deeply cleft.

ALCHEMILLA VELUTINA. Perennial, with numerous decumbent or ascending branching stems, the stems and branches appressed villous: leaves glabrous or sparingly villous, cuneate, 3-cleft, 2 to 5 lines long, the segments entire or 1–3-toothed; stipules entire or usually of two narrowly oblong lobes: flowers very small, the calyx covered with a fine velvety pubescence. — In swampy places about San Luis Potosi (870 Schaffner).

ROSA MEXICANA. Low (about a foot high), armed with straight rather slender spines (1 to 5 lines long): stipules glandular-ciliate, and the rhachis of the leaves with short stout spreading gland-bearing hairs and prickly; leaflets 5 to 7, narrow, mostly acute at each end, doubly serrate, slightly pubescent and glandular beneath, 4 to 10 lines long: flowers solitary, 1½ inches in diameter; calyx-lobes glandular-hairy, at length deciduous, the tube glabrous or very nearly so: fruit globose, 3 or 4 lines in diameter. — In the Caracol Mountains, Coahuila (2124). Allied to *R. parviflora*.

CRATÆGUS PUBESCENS, Steud. A form with broadly flabelliform or rhomboidal leaves. In the mountains east of Saltillo (2123). The Mexican species of this genus are somewhat obscure, but this appears distinguishable from *C. Mexicana* by its generally acuter and more acutely toothed leaves, which are less coriaceous when old. 50 Bourgeau ("*C. Crus-galli*") is *C. Mexicana*, as also 228 Parry & Palmer.

COTONEASTER DENTICULATA, HBK. In the Sierra Madre south of Saltillo (330); 230 Parry & Palmer.

PHILADELPHUS SERPYLLIFOLIUS, Gray. A variety with the leaves for the most part less densely pubescent beneath, similar to 1101 Wright. In the Sierra Madre south of Saltillo (2122[2]). The species is more nearly related to *P. microphyllus* than to *P. Mexicanus*.

TILLÆA ANGUSTIFOLIA, Nutt. Near Morales, San Luis Potosi (126 Schaffner); 680 Parry & Palmer.

COTYLEDON SCHAFFNERI. Acaulescent, the basal leaves narrowly lanceolate, narrowing from near the middle each way and acuminate, 3 or 4 inches long by ½ inch wide, somewhat purplish; cauline leaves rather numerous, linear, flattened, very acute, 1 to 1½ inches long: flowering stem a foot high, bearing a 2-branched raceme (the branches 4 inches long and about 8–12-flowered); pedicels very short: sepals narrowly lanceolate, unequal, 2 to 5 lines long; corolla yellow and pink, 6 to 8 lines long, nearly twice longer than the carpels. — On sandy slopes of mountains around San Luis Potosi (768 Schaffner).

Cotyledon ——— ? A somewhat similar apparently undescribed species, but the material insufficient for determination. From the same region (769 Schaffner): it was also distributed under 233 Parry & Palmer, together with specimens of still another species with broader leaves and the shortly calyculate flowers on long slender pedicels.

Cotyledon parviflora, Hemsl. In the San Miguelito Mountains (775 Schaffner).

Sedum Palmeri. Caulescent, erect and branching, glabrous and glaucous: leaves thick, flattened, spatulate-obovate, 1 to 1½ inches long by 9 lines broad (3 lines broad at base), rounded at the summit and slightly apiculate: branches slender, bearing clustered racemes (4 to 6) an inch or two long: flowers deep orange, on short pedicels, the narrowly lanceolate petals (2 or 3 lines long) but little exceeding the sepals: carpels short, about as long as the slender styles. — At Guajuco, Nuevo Leon (2121), and in cultivation at Cambridge. Resembling *S. dendroideum*, but of more slender habit and the flowers pedicellate.

Sedum ebracteatum, DC. In the Morales Mountains (774 Schaffner).

Sedum fuscum, Hemsl. In the San Rafael Mountains (778 Schaffner); 235 Parry & Palmer.

Sedum parvum, Hemsl. In the Morales Mountains (777 Schaffner); 234 Parry & Palmer.

Sedum Liebmannianum, Hemsl. Near San Miguelito (776 Schaffner).

Ammannia latifolia, Linn. At Sutherland Springs (331).

Cuphæa æquipetala, Cav. In the San Miguelito Mountains (722 Schaffner), and at Guanajuato (Dugès); 241 and 242 Parry & Palmer.

Cuphæa lanceolata, Ait. f. (*C. Zimapani*, Roezl.) In the Morales Mountains (721 Schaffner), and Guanajuato (Dugès).

Lythrum gracile, Benth. At Monterey (332), and near Morales (653 Schaffner); 245 Parry & Palmer. Typical *L. alatum*, Linn., has not been collected in Mexico. L. Kennedianum, HBK. (40 and 299 Bourgeau, 142 Coulter, 243 Parry & Palmer, &c.), which has been referred to it, is distinguished especially by its longer calyx (5 to 6 lines long), and the upper leaves less reduced. 158 Ghiesbreght, from Chiapas, is L. alatum, var. lanceolatum, Torr. & Gray, and 140 Coulter (referred to *L. Hyssopifolia*, Linn.) is var. linearifolium, Gray, collected also by Gregg at Andabago. *L. Hyssopifolia* is found in California (V. Rattan and G. R. Vasey), but there are no Mexican specimens in the Gray herbarium.

NESÆA LONGIPES, Gray. At Parras, Coahuila (333), where it was also collected by Gregg.

NESÆA SALICIFOLIA, HBK. Near San Luis Potosi (654 Schaffner); 246 Parry & Palmer.

JUSSIÆA REPENS, Linn., var. CALIFORNICA, Watson. With mostly spatulate leaves, smaller flowers and short pedicels. At Parras (334), and near Morales (173 Schaffner, together with the typical form). 247 Parry & Palmer and 183 Coulter are the same.

JUSSIÆA SUFFRUTICOSA, Linn. Near Morales (174 Schaffner).

LUDWIGIA PALUSTRIS, Linn. Near Morales (127 Schaffner).

ŒNOTHERA DRUMMONDII, Hook. In and near salt water at Corpus Christi Bay, Texas (343), with the leaves sublyrate-pinnatifid.

ŒNOTHERA MACROSCELES, Gray. At Parras, Coahuila (338). Fruiting specimens, at length collected, determine the position of this species in the *Onagra* group, where it was originally placed. The capsules are about an inch long, straight or somewhat curved, obtusely tetragonal, 1½ lines in thickness, the seeds nearly smooth or obsoletely pitted.

ŒNOTHERA SINUATA, Michx. Around San Rafael (172 Schaffner); 253 Parry & Palmer. Also the var. HIRSUTA, Torr. & Gray, at Corpus Christi Bay, Texas (345).

ŒNOTHERA SPECIOSA, Nutt. In the mountains east of Saltillo (339) and in the Caracol Mountains, Coahuila (336), and near Monterey, Nuevo Leon (335, mainly); 252 Parry & Palmer. *Œ. hirsuta* and *Œ. Berlandieri*, Walp., (*Xylopleurum*, Spach), are mere forms of this species.

ŒNOTHERA TETRAPTERA, Cav. A variety with small flowers, the calyx-tube 3 to 6 lines long, and the fruit 6 to 8 lines long including the short pedicel, from Monterey, Nuevo Leon (347). 250 Parry & Palmer is the same in part, there being with it a somewhat more villous form with larger flowers, the calyx-tube an inch long, and the fruit (5 lines long) sessile or nearly so (169 Schaffner, San Luis Potosi). With 335 Palmer, in the Gray herbarium, is a low form villous throughout with spreading hairs, even to the calyx-lobes, with larger flowers, the pedicel short and calyx-tube 6 lines long. A doubtful form was collected in the Sierra Madre south of Saltillo (340), with large flowers, the calyx-tube an inch long, and the pedicelled fruit about an inch long and attenuate at top. It is difficult to define the limits of this and the preceding species, or to draw a clear line between them. It would seem that this species is always more or less villous, and the capsule larger and more broadly winged and more abruptly contracted at top. The calyx-tube is usually shorter in proportion to the ovary, and the capsule with its pedicel often 1 to 1½ inches long.

Œnothera rosea, Ait. At Monterey, Nuevo Leon (346), in swampy places near Morales (170 Schaffner), and Guanajuato (Dugès), where it is called "Yerba del Golpe."

Œnothera brachycarpa, Gray. At Saltillo (2120), and a form with extremely narrow leaves (342). This species appears to include *Œ. Wrightii*, Gray.

Œnothera (Megapterium) dissecta, Gray, in herb. Stems slender, herbaceous, from an underground rootstock, branching, decumbent or erect, sparingly pubescent: leaves narrow, 1 or 2 inches long, pinnatifidly lobed, the linear lobes very unequal: flowers axillary, sessile, the calyx-tube 1½ inches long, slightly dilated above, the tips free in the bud; petals rose-color, an inch long: capsule oblong-ovate, narrowed at each end, half an inch long, strongly winged at least toward the top and with a prominent thick rib between the wings. — In sandy localities near San Luis Potosi (168 Schaffner); 249 Parry & Palmer.

Œnothera Hartwegi, Benth. In the mountains east of Saltillo (337, 341), and at Saltillo a form with somewhat smaller flowers (344). At Lerios a low form was sparingly collected, with linear leaves, and nearly corresponding to the variety *lavandulæfolia*. 248 Parry & Palmer is a similar but still more reduced form with small flowers.

Lopezia pumila, Bonpl. In the mountains near San Luis Potosi (640 Schaffner), and at Guanajuato (Dugès). The smaller specimens from the latter locality accord with the original description. The much larger ones from Dr. Schaffner are still more pubescent, and with leaves an inch long or more.

Lopezia trichota, Schlecht. (?) In swamps about San Luis Potosi (641 Schaffner), and at Guanajuato (Dugès); 256 Parry & Palmer. Not agreeing wholly with the description of the original specimens, which were found in rocky localities. The herbaceous stems are from a very thick perennial root, the lower leaves opposite, broadly ovate, rounded or subcordate at base, obtuse or acutish, obsoletely toothed, the upper oblong-ovate to lanceolate, acute and more acutely toothed; the narrow petals and the style pilose, the stamens glabrous.

Gaura parviflora, Dougl. At Saltillo (2119).

Gaura Drummondii, Torr. & Gray. At Laredo, Texas (348).

Gaura coccinea, Nutt. About San Luis Potosi (171 Schaffner); a narrow-leaved and a broader-leaved form, the same as 254 and 255 Parry & Palmer.

Stenosiphon virgatus, Spach. At Sutherland Springs (349).

Cevallia sinuata, Lag. At Uvalde, Texas, and at Saltillo, sparingly; at Parras, Coahuila (360), at Monterey, Nuevo Leon (361), and at San Lorenzo de Laguna a form with broader sinuately toothed leaves (362); 258 Parry & Palmer.

Petalonyx crenatus, Gray, in herb. Suffruticose, low, the short herbaceous branchlets leafy and densely retrorse-hispid: leaves oblong-lanceolate, sessile, 2 to 4 lines long, densely covered with short barbed hairs, the crenate margins revolute: flowers white, in open terminal naked racemes, each flower involucrate with three unequal toothed bractlets at the summit of the short slender pedicel: calyx-lobes linear, hispid, recurved; petals narrowly linear, not connivent, 2 lines long: filaments and style a half longer. — At San Lorenzo de Laguna, Coahuila (833).

Eucnide lobata, Gray. At Monterey, Nuevo Leon (356). This species has the leaves rather strongly lobed, with acute or acutish teeth, the inflorescence short (2 or 3 inches or less) with leaf-like toothed bracts, the calyx-lobes about 2 lines long, stamens about 60, and the oblong-ovate capsule narrowed at base. 1067 Parry & Palmer is apparently distinct, the scant specimen in the Gray herbarium showing a very short campanulate calyx and few (25 or less) stamens. The genus is clearly distinct from *Mentzelia*.

Eucnide floribunda. Stout, a foot high or more, the round-cordate leaves (1½ to 2½ inches long) slightly lobed and bluntly sinuate-toothed: inflorescence 6 to 8 inches long, with lanceolate entire bracts acute at each end: calyx-lobes 3 or 4 lines long, nearly equalling the petals: stamens very numerous (100 or more): capsule broadly campanulate, rounded at base. — At San Lorenzo de Laguna (832). Resembling *E. lobata*.

Eucnide bartonioides, Zucc. At Guajuco, Nuevo Leon (354), and at Monclova, Coahuila (355), growing on rocks at the mouth of caves. The calyx-tube in this species is villous, with the barbed pubescence very short or usually wanting, the lobes 3 to 8 lines long. Eucnide sinuata, collected by Botteri (266, in herb. Gray, without locality), is very similar, but with the leaves sinuately lobed, the obtuse lobes entire or sparingly toothed: calyx-tube densely covered with barbed hairs, the villous lobes 3 or 4 lines long.

MENTZELIA ASPERA, Linn. At Soledad (351), and in the mountains north of Monclova (831). Distinguished from the next by the annual root, smaller flowers, and longer and narrower capsule.

MENTZELIA HISPIDA, Willd. (*M. strigosa*, HBK.) At Monclova (352), Soledad (353), and in the Caracol Mountains (357); also in the mountains about San Luis Potosi (110 Schaffner), and at Guanajuato (Dugès); 257 Parry & Palmer. The root is tuberous.

MENTZELIA MULTIFLORA, Nutt. At Saltillo (350, 2105), and at San Lorenzo de Laguna (358, 359); several forms, varying in foliage, size and color of the flowers, and length of the capsule. *M. Wrightii* appears to differ only in the more shallow lobing of the leaves.

TURNERA APHRODISIACA, Ward. In the San Miguelito Mountains (166 Schaffner); 93 Parry & Palmer. Known as "Yerba de Venulo." Frequently with 4 styles and a 4-valved 8-seeded capsule.

PASSIFLORA FŒTIDA, Linn. At Laredo, Texas (2110).

PASSIFLORA TENUILOBA, Engelm. At Sutherland Springs, Texas.

PASSIFLORA BRYONIOIDES, HBK. Near San Luis Potosi (109 Schaffner); 259 Parry & Palmer.

CUCUMIS ANGURIA, Linn. At Uvalde, Texas (363).

CUCURBITA FŒTIDISSIMA, HBK. (*C. perennis*, Gray.) In the mountains near San Luis Potosi (765 Schaffner); known as "Calabazilla loco."

APODANTHERA UNDULATA, Gray. About San Luis Potosi (766 Schaffner); called "Melon loco," and the root is said to be esculent.

MAXIMOWICZIA TRIPARTITA, Cogn. At Uvalde, Texas (365), and at Laredo, on the Rio Grande (364). This species differs from *M. Lindheimeri*, Cogn. (*Sicydium Lindheimeri*, Gray; 260 Parry & Palmer), in its more narrowly lobed leaves, in the shorter campanulate tube of the calyx, in the rather smaller and more obtuse fruit, and in the narrower seeds. The var. *tenuisecta* of *M. Lindheimeri* should rather be referred to this species.

CYCLANTHERA DISSECTA, Arn. (*C. Naudiniana*, Cogn.) At Uvalde, Texas (367), and at Guanajuato (Dugès). The characters upon which Cogniaux separates his *C. Naudiniana* appear to be all unreliable.

SICYOS DEPPEI, Don. About San Luis Potosi (767 Schaffner), and at Guanajuato (Dugès), known as "Chayotillos." Closely resembling *S. angulatus*, Linn., and distinguished mainly by the smaller (3 or 4 lines long) and less villous-tomentose fruit. 397 Lindheimer, as well as 971 and 2401 Berlandier, from Texas, must be the same, though referred to *S. angulatus* by Cogniaux.

Sechiopsis triquetra, Naud. In the Cerro del Cuarto, near Guanajuato (Dugès).

Mamillaria conoidea, DC. At Saltillo (378).

Mamillaria micromeris, Engelm. At Saltillo.

Mamillaria radians, DC. In the mountains west of Saltillo. Several other undetermined species were sparingly collected.

Echinocactus longehamatus, Gal. At Saltillo (373, 374).

Echinocactus pilosus, Gal. In the mountains east of Saltillo (375).

Echinocactus horizonthalonius, Lam. At Saltillo (380).

Echinocactus bicolor, Gal. (?) At Saltillo (379).

Cereus cinerascens, DC. At San Lorenzo de Laguna (368, 369), Parras (370, 371), and Saltillo (372), some with larger spines than any described; 368 is doubtful; 277 Parry & Palmer.

Opuntia Kleiniæ, DC. At San Lorenzo de Laguna (376).

Opuntia imbricata, DC. At Parras (377).

Mollugo Cerviana, Ser. At Bluffton, Texas (381). This species has been recently collected also in New Mexico and Arizona.

Mollugo verticillata, Linn. Western Texas (382); San Luis Potosi (118 Schaffner); 283 Parry & Palmer.

Glinus Cambessidesii, Fenzl. At San Lorenzo de Laguna (72). With smaller flowers and much smaller seeds and generally less pubescent than *G. lotoides* of the Old World, to which the Mexican specimens are referred by Hemsley. The strophiolate seeds with elongated funicles, together with some peculiarities of habit, rather justify the retention of the genus.

Hydrocotyle prolifera, Kellogg. At Georgetown, Texas (383). The same as 107 Coulter and 1068 Parry & Palmer (referred to *H. interrupta*), and 480 Bourgeau.

Eryngium nasturtiifolium, Juss. At San Lorenzo de Laguna (384); 1112 Parry & Palmer.

Eryngium Deppeanum, Cham. & Schlecht. In woods near Morales (7 Schaffner); 285 Parry & Palmer, referred to *E. aquaticum*, Linn.

Eryngium serratum, Cav. On rocks, near Morales (8 Schaffner), and at Guanajuato (Dugès); 284 Parry & Palmer. Known as "Yerba del sapo."

Eryngium yuccæfolium, Michx., var. (?) Basal leaves short and narrow, margined with long slightly rigid setæ: rays slender and elongated, erect: heads small; floral bracts puberulent. — In the Caracol Mountains, southeast of Monclova (417).

Eryngium carlinæ, Delar. In sandy places near San Luis Potosi (6 Schaffner); 286 Parry & Palmer, referred to *E. Wrightii*, which differs chiefly in the much more conspicuous rigid and spinose floral bracts.

Eulophus Texanus, Benth. & Hook. At Lerios, Coahuila (386).

Eulophus peucedanoides, HBK. In the Sierra Madre, south of Saltillo (Palmer, sparingly), and near San Miguelito (5 Schaffner); 292 and 293 Parry & Palmer.

Apium leptophyllum, F. Muell. At San Lorenzo de Laguna (385), at Monterey (2109, in part), and about San Luis Potosi (2 Schaffner); 294 Parry & Palmer. In several forms.

Apium Popei, Gray. At Monterey, Nuevo Leon (2109, in part).

Crantzia lineata, Nutt. Near Morales (1 Schaffner); 287 Parry & Palmer.

Discopleura laciniata, Benth. & Hook. At Sutherland Springs, Texas.

Peucedanum Mexicanum. Glabrous, the stout erect stem 2 or 3 feet high or more: leaves with a broadly dilated sheathing petiole, at least thrice ternate, the ultimate segments from linear to narrowly lanceolate, elongated, acute and acutely toothed or laciniate: umbel naked or with a few linear bracts, the rays (6 to 20) ½ to 1½ inches long; bracts of the involucels very narrow: flowers white: fruit very broadly elliptical (4 or 5 lines long by 3 or 4 broad), on pedicels 1 or 2 lines long, with thin wings and numerous vittæ, the dorsal ridges filiform: seed flattened-reniform, scarcely at all sulcate on the back, but with a shallow channel on the face. — On rocks near Morales (4 Schaffner); 288 Parry & Palmer. Known as "Ococotillo." 316 and 571 Bourgeau, referred to *Peucedanum* by Hemsley, are *Angelica Mexicana*, Vatke. Though certainly an *Angelica* rather than a *Peucedanum*, yet it is somewhat anomalous in some of its characters.

Daucus montanus, Willd. At San Luis Potosi (3 Schaffner); 291 Parry & Palmer.

Garrya ovata, Benth. In the San Miguelito and San Rafael Mountains (888, 889 Schaffner); 295 Parry & Palmer, referred to *G. laurifolia*.

Garrya laurifolia, Hartw. In the San Rafael Mountains (890 Schaffner).

2. *Descriptions of New Species of Plants, chiefly from our Western Territories.*

MYOSURUS CUPULATUS. Scapes slender, 2 to 6 inches high: anthers oblong, much shorter than the filaments: fruiting heads loose, long-conical, about an inch (3 to 16 lines) long: akenes short and subquadrate, cupulate at the summit with a raised and at length irregularly thickened light-colored margin, and with a broadly triangular slightly curved ascending beak. — Arizona; hills between the Gila and San Francisco Rivers, Rev. E. L. Greene; on the Santa Catalina Mountains, at 8,000 feet altitude, J. G. Lemmon; found by both collectors in April, 1880. Readily distinguished in fruit by the peculiar akenes. In habit it resembles *M. minimus*, which has less attenuated closely compact heads, on often very stout scapes, the rectangular akenes truncate and beakless or with a very short strictly appressed beak; the anthers linear and nearly equalling the filaments. In the usually small *M. aristatus* the loose heads are rarely more than 3 or 4 lines long, the oblong-ovate akene with a long slender somewhat spreading beak.

MYOSURUS SESSILIS. Without scapes, the flowers sessile or very nearly so: fruiting heads usually several (1 to 6) and crowded, much shorter than the leaves, stout and conical (2 to 6 lines long by a line or more in thickness at base): akenes with a prominent costa terminating in an erect or spreading subulate beak. — On alkali flats in Umatilla County, Oregon; J. & T. J. Howell, May, 1882.

ARABIS FURCATA. Perennial, the slender stems ascending from a slender branching rootstalk, a foot high or more, glabrous: leaves sparingly pubescent and ciliate with branched hairs, the lower petiolate, oblong-obovate, acutish, with few teeth, an inch or two long, the cauline sessile, oblong to linear, mostly glabrous: flowers white, 3 to 5 lines long, with yellowish sepals: pods narrow, ½ to 1½ inches long, beaked by the thick style, on slender spreading pedicels 6 to 10 lines long. — On the bluffs of the Columbia, near the mouth of Hood River, Oregon; J. & T. J. Howell, in 1879, and with immature fruit in May, 1882; received also from Mrs. P. G. Barrett, of Hood River. A dwarf alpine form, with shorter pedicels, was collected on Mount Adams at the White Salmon glacier by W. N. Suksdorf in 1877, and again in 1879.

ARABIS SUFFRUTESCENS. Perennial, with a decidedly woody branching base, glabrous or sparingly stellate-pubescent, the erect subfastigiate stems a foot high: lower leaves linear-oblanceolate, acute, about an inch long, the cauline more oblong and sessile or shortly auriculate-clasping: raceme few- (4–6-) flowered: sepals broad, the purplish petals twice longer (3 lines long): pods reflexed on pedicels 4 to 6 lines long, attenuate to a short style, 1½ to 2½ inches long by 1½ lines broad: seeds somewhat in two rows, orbicular, winged. — Collected on the bluffs of the Snake River and vicinity, Union County, Oregon, by W. C. Cusick, 1881.

Arabis Cusickii. Perennial, villous-pubescent throughout with loose scattered spreading simple hairs, the clustered leafy stems 3 to 5 inches high: lower leaves linear-oblanceolate, about an inch long, the upper linear-oblong and clasping but not auriculate at base, all entire or sparingly toothed: flowers few, pale pink or white, turning light purple, the petals three or four lines long, twice longer than the sepals and exceeding the pedicels: pods falcate, ascending, acutish, 1½ to 3 inches long by about a line broad; style none: seeds acutely margined. — On rocky ridges, Union County, Oregon; W. C. Cusick, 1879. Resembling *A. canescens* in habit, which is hoary with short dense stellate pubescence, and appears to have much smaller flowers.

Streptanthus diversifolius. Annual, glabrous, erect and slender, branching above, 1 to 1½ feet high: cauline leaves very narrow, pinnately divided with 1 or 2 pairs of narrowly linear lobes, the upper entire or nearly so; those on the branches broadly cordate and clasping, entire, ½ inch long or less: racemes few-flowered; pedicels divaricately spreading, 1 or 2 lines long: sepals 2 or 3 lines long, pale; petals with a rather broad exserted recurved blade, purple-veined: pods strongly reflexed, 1½ to 2½ inches long by less than a line broad. — On the Cosumne Creek, California; collected by V. Rattan in 1866.

Physaria Oregona.* Flowers apparently pale-yellow, the petals (3 or 4 lines long) twice longer than the calyx: style very short, less

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* The species of *Physaria* may be distinguished as follows. —

* Cells of the pod much inflated and much longer than the replum.

1. P didymocarpa. Nutt. Cells very obtuse and divergent. — From Colorado to British America and Eastern Washington Territory.

2. P. Newberryi, Gray. Cells less divergent. — New Mexico to Utah and Nevada? An obscure species.

* * Cells more or less compressed and but little exceeding the replum.

3. P. Geyeri, Gray. Pods small, obcordate; style as long as the pod. — Spokan Valley, Washington Territory

4. P. Oregona, Watson. Pods large, round-reniform; style very short. — Eastern Oregon.

than a line long: pod obcompressed, 5 to 10 lines broad, the narrowly linear replum 3 or 4 lines long, and the flattened obtusely rounded cells 1–4-seeded. — In gulches on Pine Creek, near Snake River, Union County, Oregon; W. C. Cusick, June, 1880. With the habit and foliage of the other species, but with the flattened pod of *Synthlipsis,* though the valves are nerveless and not carinate.

DRABA CHRYSANTHA. Perennial, with leafy decumbent or erect stems (2 to 6 inches high) from a branching rootstock, which becomes covered with the persistent bases of dead leaves, sparingly pubescent with simple hairs: basal leaves narrowly oblanceolate, 1 to 2½ inches long, entire or occasionally with 1 or 2 teeth, sparingly ciliate, the cauline oblanceolate to lanceolate: raceme open, the bright yellow flowers on slender pedicels 2 to 6 lines long: pod glabrous, oblong (4 or 5 lines long), acute at each end and beaked by a slender style ½ to 1 line long. — In the high mountains of Colorado (above Golden City, at 12,500 feet altitude, Rev. E. L. Greene, 1871, and in the Sawatch Range, T. S. Brandegee, 1880), and on a peak south of Apache Pass, Arizona, J. G. Lemmon, 1881.

CAULANTHUS AMPLEXICAULIS. Annual, glabrous and glaucous, branching, suberect or lax and flexuous, 1 to 2 feet high: lower leaves oblong-obovate, obtuse, auriculate and clasping, coarsely and acutely toothed or sparingly denticulate or entire, 2 to 4 inches long, the upper round-ovate to oblong-ovate, entire, the uppermost more acute: racemes very loose: sepals 3 to 5 lines long; petals with a narrow recurved exserted limb, purple-veined: pods terete, about 3 inches long by ⅔ of a line wide, spreading or ascending on pedicels 3 to 6 lines long or more, with a thick bifid sessile stigma. — In the San Bernardino Mountains, California; collected in May, 1881, by S. B. & W. F. Parish, and by W. G. Wright.

CAULANTHUS GLAUCUS. Glabrous and glaucous, stout, simple or sparingly branched, 1 to 2½ feet high: leaves rather fleshy, all petiolate, ovate to lanceolate, more or less narrowed at base, obtuse or acutish, the blade 1 or 2 inches long: sepals purplish, 4 lines long; petals greenish, exserted: pods subterete, very slender, 3 to 5 inches long, arcuate upon ascending pedicels 3 to 6 lines long, the conical sessile stigma slightly bifid. — At Candelaria, Esmeralda County, Nevada; W. H. Shockley, 1881.

CAULANTHUS INFLATUS. Annual, sparingly hispid or glabrous, erect, simple or at length branched, the stem fistulous and inflated, 1 or 2 feet high: leaves oblong to ovate, all sessile and auriculate, acutish, entire, 1 to 3 inches long: flowers purple, the glabrous sepals somewhat saccate at base, 3 or 4 lines long; petals ligulate, scarcely exserted: pods nearly terete, 3 or 4 inches long, ascending on pedicels 2 to 4 lines long; stigma sessile, deeply bifid. — In the Mohave Desert, California; collected by J. G. Lemmon in 1880, and by the Parish Brothers in March, 1882. With the habit of *C. crassicaulis*.

THLASPI CALIFORNICUM. Biennial, the several stems 6 to 8 inches high, glabrous: lower leaves oblanceolate, attenuate to a slender petiole, with few teeth, the upper oblong-lanceolate, narrower toward the base and usually narrowly auriculate: flowers rather small, the petals 2 lines long: pods oblanceolate, acute at the summit, 4 or 5 lines long; cells 2–5-seeded. — At Kneeland Prairie, Humboldt County, California, among rocks at 2,500 feet elevation; discovered by Mr. Volney Rattan, June, 1882. Differing from the alpine *T. alpestre*, which is usually a perennial, in its narrower oblong stem-leaves and in its longer acute pod, which is exactly that of *Iberidella*.

CLEOMELLA BREVIPES. Low and branching (6 inches high or less), glabrous, leafy: leaves sessile or nearly so, the leaflets narrowly oblanceolate, setosely apiculate, 2 to 8 lines long: flowers very small, solitary in all the axils, on curved pedicels about a line long: pod ovate, pendulous, very shortly stipitate, 1½ lines long. — At Camp Cady in the Mohave Desert, California; S. B. & W. F. Parish, May, 1882. Very peculiar in its axillary inflorescence, and short pedicels and stipes.

CLAYTONIA CORDIFOLIA. Stems 4 to 12 inches high from a slender running rootstock, bearing toward the summit a single pair of sessile ovate acute leaves about an inch long; radical leaves broadly cordate, acutish, the blade 1 or 2 inches long: flowers few (about 6 or 8) upon slender pedicels in a naked raceme; petals 3 or 4 lines long, thrice longer than the rounded sepals. — Collected by Dr. Lyall in 1861 on the Pend d'Oreille River in N. Idaho, and in Oregon by Rev. R. D. Nevius in 1872; found by me in 1880 in the mountains north of Missoula, Montana, in the damp shade of firs and spruces. Nearly allied to *C. Sibirica*, differing in the shape of the leaves, the naked few-flowered raceme, and more rounded sepals.

CLAYTONIA AMBIGUA. Root thickish and fusiform: stems branching from the base, low, stout and fleshy, leafy: leaves alternate, narrowly oblanceolate, obtuse, 1 or 2 inches long: flowers in axillary subsessile fascicles or short crowded racemes, with scarious bracts, the pedicels 1 to 3 lines long; petals unequal, shorter than the sepals, which are 1½ to 2 lines long: stamens 5: capsule ovate-oblong, shorter than the calyx, 12–15-seeded: seed shining. — Plains at El

Rio on the Colorado, S. E. California, by J. G. Lemmon, March, 1881. A peculiar species, with the numerous seeds of a *Calandrinia*, but the flowers more like those of *Claytonia*, and the number of stamens constant.

Silene Parishii. Perennial, the leafy stems (4 to 6 inches high) clustered upon a thick root, pubescent throughout with a short wool which is longer on the stems and viscid: leaves oblanceolate, acute or acuminate, 1 or 2 inches long: flowers 3 to 5, approximate and leafy-bracted, on short petioles; calyx an inch long, narrowed below, the acuminate teeth 3 or 4 lines long; petals white or nearly so, with a broad claw, the scarcely exserted blade 2-parted and the lobes deeply bifid into hairy filiform segments with a narrow lateral one on each side; appendages broad, truncate and toothed: styles at length long-exserted: capsule very shortly stipitate, nearly equalling the calyx: seeds flattened, with a wing-like lacerate double crest. — In the San Bernardino Mountains, California; L. B. & W. F. Parish, August, 1881. A well-marked species, allied to *S. Hookeri* and *S. Californica*.

Silene platyota. Minutely puberulent, glandular above, the slender erect or ascending stems $1\frac{1}{2}$ feet high: leaves oblanceolate, acute or acuminate, the lower with ciliate winged petioles: peduncles rather slender, 1–3-flowered: calyx narrow, green-nerved, acutely toothed, 6 lines long; petals greenish, broadly auricled, the free lobes of the auricles entire or sublacerate; blade bifid, the oblong lobes entire or usually irregularly notched; appendages oblong, lacerate; filaments and claws somewhat villous: styles and stamens slightly exserted: capsule oblong, 4 lines long, on a short stipe: seed crested with a single row of tubercles, the sides tessellated. — In the Cuyamaca Mountains (Dr. E. Palmer, 1875), in the San Bernardino Mountains (J. G. Lemmon, 1879), and in the San Jacinto Mountains (Parish Brothers). Belonging to the *S. Douglasii* group.

Silene plicata. Rather stout and tall (2 feet high or more), pubescent with short spreading somewhat glandular hairs: leaves oblanceolate, or the upper narrowly lanceolate, acute, 3 or 4 inches long: inflorescence elongated, naked above, the erect peduncles 1–3-flowered: calyx ovate, with 10 green nerves, 4 lines long, the triangular teeth a third as long; petals white, a little exserted, the blade bifid with oblong lobes and narrow acute lateral teeth, the claw broad and the produced auricles nearly equalling the short-oblong entire appendages and somewhat folded upon the base of the blade: stamens and styles included: capsule sessile or nearly so, ovate-oblong, 4 or 5 lines long: seeds strongly tuberculate on the back, not crested.— On a peak south of Rucker Valley, Arizona; J. G. Lemmon, 1881. Allied to *S. Thurberi.*

ARENARIA PUSILLA. A dwarf slender annual, an inch or two high, resembling *A. Californica* in its habit and short thick bluntish leaves, but the narrower lanceolate sepals acute or acuminate and obscurely 1-nerved, and the petals wanting or very small: capsule oblong-ovate, as long as the sepals: seeds turgid, smooth. — Collected on the plains about Yreka, California, by Rev. E. L. Greene, in April, 1876; at White Salmon, Washington Territory, by W. N. Suksdorf, in 1880; and at The Dalles, Oregon, by J. & T. J. Howell, 1882. Greene's specimens were referred to *A. Californica* in Bot. Calif. 2. 435.

ARENARIA MACRADENIA. Perennial, with a branched woody rootstock, the herbaceous stems a foot high, glabrous throughout excepting the slightly ciliate base of the rigid linear-subulate pungent leaves, which are ½ to 2 inches long: flowers large, on slender often elongated pedicels; sepals somewhat fleshy, with scarious margins, ovate, acute, nerveless, 2 or 3 lines long; petals greenish-white, entire, exserted: stamens included, the filaments opposite to the sepals with a pair of large yellowish glands adnate to the base: stigmas subcapitate: capsule ovate-globose, 1½ lines long. — Near the Mohave River (41 Palmer, 1876), and in the mountains bordering the Mohave Desert (S. B. & W. F. Parish, May, 1882). Remarkable among the allied perennial species for the large glands of the staminiferous disk.

LEPIGONUM GRACILE. Annual, slender, glabrous, 2 to 4 inches high: leaves very narrow, 3 to 12 lines long; stipules deltoid: pedicels ascending, 2 to 4 lines long: sepals fleshy, short, obtuse, ½ to nearly 1 line long: petals none: capsule ovate, equalling or a little exceeding the calyx: seeds triangular-pyriform, strongly rough-tuberculate, not margined. — Common on sandy lands near Dallas, Texas (J. Reverchon), and in dried ponds on mesa land near Wilmington and Compton, Los Angeles County, California (Rev. J. C. Nevin). It is nearly allied to the European *L. segetale*, and also to *L. Mexicanum*, from which it differs especially in its smaller calyx and capsules, and more angular and rougher seeds.

MALVASTRUM RUGELII. Woody-stemmed, erect and branching (2 or 3 feet high or more), rather sparingly pubescent with straight appressed forked hairs: leaves ovate to oblong-ovate, abruptly narrowed at base, acutish, acutely serrate, ½ to 1½ inches long, exceeding the petioles: flowers nearly sessile, solitary or few in the upper axils and in a short crowded terminal spike: calyx-lobes triangular, acute or subacuminate, usually closing over the fruit; corolla apparently yellow, 2 or 3 lines long: carpels rounded and blunt. — Collected by Rugel at the mouth of the Manate River, Southwestern Florida, in 1845, and distributed by Shuttleworth as a variety of *Malva Americana*, Linn. It was also collected by Dr. Garber in 1877 on the Miami River, and by A. H. Curtiss on the Mosquito Lagoon, and distributed by him under the name *Melochia serrata* in his third fascicle. It resembles most nearly *M. tricuspidatum*, but with the blunt carpels of *M. spicatum*.

MALVASTRUM DENSIFLORUM. Perennial, stout, erect and branched, 2 feet high or more, roughly stellate-pubescent: leaves round-cordate, somewhat 3-lobed, crenately or acutely toothed, 1 to 1½ inches in diameter, the petioles usually much shorter: inflorescence dense and very hispid, the conspicuous bractlets very narrow, hispid, exceeding the calyx: fruiting calyx 6 to 8 lines long, membranous, the lobes long-attenuate; corolla apparently purple, 6 to 8 lines long: stamineal column very short: carpels smooth and nearly glabrous, obtuse. — Southern California, at Agua Caliente in the San Jacinto Mountains (S. B. & W. F. Parish, and W. G. Wright, 1881), and at San Juan Capistrano (Rev. J. C. Nevin).

ANODA RETICULATA. Annual, erect, simple or sparingly branched above, 2 feet high, finely stellate-pubescent: leaves broadly ovate, truncate or cordate at base, and often more or less hastately lobed, acute or acutish, dentate, an inch long or less, the upper linear-hastate and the uppermost reduced to minute bracts: pedicels slender, 1 to 3 inches long: petals blue, 3 lines long, twice longer than the calyx: carpels 10, truncate above and rounded on the back, with a double wall, the outer wholly open at the sides, the inner enclosing the seed and deciduous with it, strongly reticulated and at length perforated, and dark-colored: seed a line long. — In the Santa Catalina Mountains, Arizona; J. G. Lemmon and C. G. Pringle, May, 1881. Remarkable for the character of the double-walled carpels, an approach to which is also found in *A. parviflora* (*A. Wrightii*).

HERMANNIA PAUCIFLORA. Branching from the woody base, a foot high or less, stellately pubescent: leaves ovate to ovate-oblong, cordate or truncate at base, 6 lines long or less, on short petioles, dentate: flowers solitary in the axils, on slender pedicels; the yellow petals (4 lines long) twice longer than the acutely lobed calyx, which is not enlarged in fruit: styles distinct or coherent at the apex. capsule 4 or 5 lines long, the dorsal crest of the carpels with short rather blunt teeth. — In the Santa Catalina Mountains, Arizona; C. G. Pringle, 1881. Our other species, *H. Texana*, Gray, is taller, with the twice larger reddish flowers more or less panicled, the calyx-lobes more acuminate, the petals more abruptly contracted to a comparatively narrower claw, and the carpels pectinately crested. The narrowed base of the erect petal is in both species strongly concave or channelled.

LUPINUS PLATTENSIS. (*L. ornatus*, Dougl., var. *glabratus*, Watson.) Stems herbaceous from an underground rootstock; appressed silky-villous throughout, with a somewhat glaucous hue: leaflets 7 to 9, spatulate, acutish or obtuse, glabrous above, on rather short petioles: racemes loose, shortly peduncled; bracts short, deciduous: flowers half an inch long, pale blue, with a conspicuous darker spot upon the standard. — A readily recognized species, common on the Upper Platte and northward.

LUPINUS HAVARDI. Apparently perennial, the several herbaceous stems 1 to 1½ feet high, leafy, at length branched, loosely appressed silky-villous throughout, the pubescence upon the stems mostly short: leaflets 7, oblanceolate, glabrous above, 4 to 10 lines long, short-petioled; stipules very narrow, elongated: raceme elongated, the deciduous bracts shorter than the narrow slightly gibbous calyx: petals purple with a light spot on the standard, broad, 6 lines long: pod narrowly linear, 12 to 18 lines long by 2 broad, 6–8-seeded. — Hills near Presidio, W. Texas; Dr. V. Havard, U. S. A., May, 1881. Allied to *L. sericeus*, *L. Sitgreavesii*, and some Mexican species, and the most eastern representative of the group.

DALEA RUBESCENS. (*D. nana*, Torr., var. *elatior*, Gray, Pl. Wright. 1. 46.) With the simple tall erect stems and dense oblong heads of *D. aurea*, but more slender, the leaves pinnately trifoliolate, and the flowers smaller, the yellow petals becoming purplish. — Western Texas; at the Limpia Pass, 124 Wright, and at Fort Davis, Dr. V. Havard, 1881.

DALEA SCARIOSA. Glabrous and glaucous, the herbaceous stems slender and branching: leaflets 7 to 9, cuneate-obovate, obtuse or retuse, 3 or 4 lines long; lower half of the rhachis naked: spike dense, becoming 2 inches long and open in fruit, on a short peduncle; bracts thin and greenish, ovate, acuminate, the white margin somewhat lacerate: calyx slightly pubescent and obscurely ribbed, the acuminate narrowly deltoid teeth about half the length of the tube and somewhat tomentose on the margin; petals pink. — Near Albuquerque, New Mexico; Rev. E. L. Greene, 1877.

ASTRAGALUS TERMINALIS. Perennial, canescent with a fine white appressed pubescence, the slender stems 6 to 10 inches long: leaves long-petiolate, with broad triangular stipules; leaflets 6 to 8 pairs, linear-oblong to oblong-obovate, obtuse, 3 to 5 lines long: raceme an inch long, open, long-pedunculate: flowers nearly sessile, reflexed, purplish, 5 lines long: calyx campanulate, the teeth very short and broad; keel with a very short blunt purple beak: pod coriaceous, sessile, straight, erect, narrowly oblong and turgid, 6 lines long, narrowly channelled on the back and nearly 2-celled, the ventral suture prominent. — Southern Montana, on the gravelly bank of Red Rock Creek, in July, 1880, near the then terminus of the Utah and Northern Railroad; S. Watson. Nearly allied to *A. adsurgens*.

ASTRAGALUS GIGANTEUS. Perennial, the stout erect stems 2 to 3 feet high or more, tomentose: leaves villous-pubescent and subtomentose; leaflets 5 to 10 pairs, oblong-ovate, acute, 6 to 9 lines long, less pubescent above; stipules broad: racemes short and rather few-flowered, erect, pedunculate: pods 2-celled, coriaceous, ovate, acuminate, somewhat compressed and the ventral suture impressed, sessile, erect, 9 lines long. — At Fort Davis, Western Texas; Dr. V. Havard, 1881. Flowers unknown. A striking species, which seems to have escaped all previous collectors.

ASTRAGALUS GRANDIFLORUS. Dwarf, densely cespitose and scarcely caulescent, covered throughout with a subappressed villous pubescence: leaflets 7 or 9, oblong-obovate to nearly orbicular, 2 to 5 lines long: peduncles shorter than the leaves (1 to 1½ inches long), few-flowered: calyx cylindrical, about 9 lines, the narrow teeth 2 or 3 lines long; petals purplish-red, 16 to 18 lines long, the claws exserted, and the keel nearly straight and erect: ovary densely white-silky, sessile, narrowly oblong, 1-celled. — In the San Bernardino Mountains, toward the Mohave Desert, at 5,000 feet altitude; S. B. & W. F. Parish, May, 1882. Evidently belonging to the group of *Eriocarpi*, with unusually large reddish flowers.

ASTRAGALUS VASEYI. Near *A. Hornii* and *A. crotalariæ*, apparently biennial, canescent with appressed silky pubescence, a foot high or less: leaflets 7 to 10 pairs, obtuse or acutish, mucronate, 3 to 8 lines long: peduncles exceeding the leaves; raceme rather loose: calyx-teeth acuminate-deltoid, little shorter than the campanulate tube; petals purple or purplish, 4 lines long: ovary silky; pod membranous, ovate-oblong with a straight ventral suture, sessile, usually reflexed, finely pubescent, about 9 lines long. — At Mountain Springs, San Diego County, California, by G. R. Vasey, 1880, and by several collectors since from various localities in the mountains of San Bernardino and San Diego Counties.

Astragalus conjunctus. Perennial, with very short stems, very sparingly appressed-pubescent: leaflets 5 to 10 pairs on an elongated rhachis, linear, 4 to 6 lines long: peduncles elongated (6 to 12 inches high), bearing an open few-flowered raceme; pedicels very short: calyx narrowly tubular, 3 or 4 lines long, dark-pubescent, with short narrow teeth: petals pale purple, 6 to 8 lines long: pod coriaceous and rugose, erect, sessile, narrowly oblong and nearly straight, acuminate, 1-celled with the dorsal suture impressed, 9 to 12 lines long. — In John Day Valley, Oregon (J. Howell, in May, 1880), and on sterile rocky ridges in Baker County, by W. C. Cusick, 1881.

Lathyrus Cusickii. Glabrous or sparingly pubescent, slender, from a slender perennial rootstock, ½ to 2 feet high, without tendrils: stipules narrowly semisagittate; leaflets 2 or 3 pairs, linear-lanceolate to narrowly linear, acute or acutish and mucronate, 2 or 3 inches long: peduncles equalling or exceeding the leaves, 2–3- (rarely 5-) flowered: corolla white, 10 to 12 lines long; the calyx 3 or 4 lines long, with nearly equal teeth. pod attenuate to a narrow base, 1½ to 2 inches long by 3 lines broad: hilum short. — On dry mountain slopes, Union County, Oregon; W. C. Cusick. Resembling narrow long-leaved forms of *L. palustris*, but with much larger white flowers, the tendrils wholly wanting, and the hilum of the seed much shorter.

Desmanthus obtusus. Decumbent, finely pubescent: pinnæ usually two pairs, upon a very short rhachis (rarely ½ inch long); leaflets oblong, veined: head small and few-flowered, on peduncles much exceeding the leaves (1 to 2½ inches long): pods narrowly linear (8 to 16 lines long), straight, obtuse or slightly narrowed at base, obtuse and apiculate at the apex. — Western Texas; Dr. V. Havard, August, 1881. Allied to *D. reticulatus*, Benth.; see page 349.

Ivesia Utahensis. Alpine, the short caudex densely covered with the remains of dead leaves, viscid-pubescent but the pubescence less glandular above, the prostrate stems ½ to 1½ feet long: leaves mostly radical, about 2 inches long, with numerous approximate 3–5-parted leaflets, the segments oblong-oblanceolate, obtuse, 1 or 2 lines long; cauline leaves few, short and with few nearly entire leaflets; stipules large, ovate: inflorescence somewhat dense: calyx 1½ to 2 lines long, the teeth equalling or exceeding the tube, and the accessory lobes narrow; petals white or pinkish, narrowly spatulate, slightly exceeding the sepals: stamens 10: pistils 1 to 3, on a very villous receptacle. — On the summit of Bald Mountain in the Wahsatch range, above Alta, at over 12,000 feet altitude; Marcus E. Jones, August, 1879.

SAXIFRAGA ERIOPHORA. Radical leaves oblong-ovate, dentate, obtuse, glabrous above, reddish and more or less densely rufous-tomentose beneath, the broad petiole equalling the blade (about ½ inch long) and ciliate with long woolly hairs: scape glandular-pubescent, the flowers subcymose, with linear-lanceolate bracts: calyx glabrate, broadly campanulate, the purplish lobes broad and rounded, half the length of the spatulate pinkish petals: ovary 2-parted, adnate to the calyx at base. — On the northern slope of the Santa Catalina Mountains, Arizona, at 6,000 feet altitude; J. G. Lemmon, May, 1881. Resembling *S. Virginiensis* and *S. nivalis*.

SEDUM DIVERGENS. Perennial, the rather stout stem 2 to 4 inches high: lower leaves broadly ovate or obovate, sessile, 3 or 4 lines long, the cauline narrower and somewhat spatulate: inflorescence close, with short branches: flowers yellow, pedicellate, the lanceolate petals (3 lines long) thrice longer than the triangular-ovate sepals, and equalling the stamens: carpels united at base, very widely divergent above. — In the Cascade Mountains, Washington Territory; on Mount Adams, by W. N. Suksdorf, September, 1880, and by myself near the summit of Yakima Pass, October, 1880.

SEDUM DIVARICATUM. Perennial and cespitose, with slender branching rootstocks, the lower rosulate leaves oblanceolate, obtuse or acutish, roughish on the margin, 6 lines long or less: flowering stems 2 to 8 inches high, with scattered oblanceolate leaves, or the upper leaves and bracts lanceolate: inflorescence umbellate, the branches once forked: flowers nearly sessile, bright yellow, with short lanceolate sepals and narrowly lanceolate acuminate petals: carpels broadly divergent above the united bases. — Collected by W. C. Cusick in Union County, Oregon. These two species resemble in their spreading carpels *S. Douglasii*, which is distinguished by its lanceolate acuminate leaves.

COTYLEDON VISCIDA. Shortly caulescent: leaves numerous and very viscid, linear to linear-lanceolate, attenuate upward and obtusely triquetrous, the outer about 3 inches long: flowering stems slender, a foot high, with similar leaves ½ inch long: flowers in a spreading cymose panicle, on pedicels 1 or 2 lines long; sepals purplish, ovate-lanceolate, 1½ lines long, the reddish corolla cleft to below the middle, 4 lines long and equalling the stamens and styles. — Abundant on rocks near the Hot Springs at San Juan Capistrano, Los Angeles County, California; Rev. J. C. Nevin, October, 1881.

Cotyledon Oregonensis. Flowering stems 6 to 10 inches high, from a running rootstock, the rosulate basal leaves spatulate, obtuse, 8 to 15 lines long: cauline leaves oblong-spatulate, 6 lines long or less: peduncles axillary along the upper stem, ½ to 1 inch long, bearing short simple or compound few-flowered racemes; pedicels a line or two long, with small bractlets: sepals deltoid, short; petals pale yellow, united to below the middle, 4 lines long: stamens slightly shorter. — Found in the Cascade Mountains, Northern Oregon, by J. & T. J. Howell, June, 1880. A peculiar species, both in its habitat and in its inflorescence.

Œnothera (Chylismia) heterochroma. Annual, erect (a foot high), sparingly branched above, glandular-pubescent throughout: leaves ovate-lanceolate (an inch long or less), dentate or nearly entire, the villous pubescence less glandular; floral bracts minute: flowers in nearly strict racemes, erect on short slender pedicels, calyx-tube narrowly obconical (1½ lines long), about equalling the lobes; petals purple with whitish base: capsule clavate, 4 lines long: seeds oblong-obovate. — At Candelaria, Esmeralda County, Nevada; W. H. Shockley, 1881.

Œnothera (Sphærostigma) refracta. Annual, erect, diffusely branching, about a foot high, somewhat glandular-puberulent: leaves narrowly lanceolate to linear, slightly sinuate-toothed, 1 or 2 inches long: flowers sessile, axillary and spicate, the upper approximate and nodding in bud: calyx-tube narrowly obconic, 2 to 2½ lines long; petals pale-yellow, 2 or 3 lines long: stigma large and spherical, exserted: capsule slender, nearly terete, striate, straight or somewhat curved, 10 to 18 lines long, at length usually abruptly reflexed: seeds linear, nearly white. — Southern California to Southern Utah, from several collectors. First collected by Dr. Bigelow near the Colorado (*Œ. dentata*, Torr. in Pacif. R. Rep. 4. 87, in part), and distributed as *Œ. strigulosa*, var., in Palmer's collection of 1876 in Arizona and S. Utah (n. 165). It has also been mistaken for *Œ. alyssoides*, and is in some respects intermediate between the two species.

Echinocystis (?) parviflora. Stem very slender, glabrous: leaves scabrous above, an inch long or less, cordate, acute, deeply 3-lobed, the lateral lobes somewhat quadrate: tendrils not branched: flowers numerous, minute, white, in very slender sessile panicled racemes, the pistillate solitary in the axils of the panicle and shortly pedicellate; corolla rotate, deeply 5-cleft, a line wide: anthers 3, nearly sessile, united, recurved: ovary semi-obovate, with a long filiform beak (the whole 3 lines long), compressed, sparingly echinate, 1-celled and 1-ovuled; ovule erect: stigma capitate, scarcely lobed. — In the San Bernardino Mountains, California; W. G. Wright, 1880. An apparent congener of *Elaterium Bigelovii*, Watson, which is referred to *Echinocystis* by Cogniaux. His reference is here followed provisionally, but the species are probably to be separated as a distinct genus.

DEWEYA VESTITA. Acaulescent, with a stout rootstock, densely covered throughout with white soft spreading hairs: leaves compoundly pinnate, the numerous crowded confluent segments oblong, obtuse or acute, a line or two long: peduncles about equalling the leaves, 2 or 3 inches high; involucre none; rays numerous, stout, nearly an inch long; bracts of the involucels several, short, lanceolate; sterile secondary rays slender, ½ inch long or more: fruit sessile or nearly so, pubescent, 2½ lines long. — Summit of Mount Baldy, near San Bernardino, California; S. B. & W. F. Parish, August, 1880. A very peculiar species.

ANGELICA LYALLII. Stout, 4 or 5 feet high, glabrous: leaves ternate-quinate, the leaflets 3 or 4 inches long (or in the upper leaves 1 to 3 inches), lanceolate, acute or acutish, mostly cuneate at base, unequally dentate: umbels 30–50-rayed, wholly naked; rays very unequal (1 to 3 inches long): fruit glabrous, 2 lines long, the dorsal ribs thick and corky. — Collected by Dr. Lyall in the Galton and Cascade Mountains, near the British Boundary, in 1859 and 1861; by Rev. R. D. Nevius in Oregon, in 1873; and by myself in the mountains near Missoula, Montana, in 1880. A. GENUFLEXA, Nutt., from Oregon and Washington Territory, is a more slender species, more or less rough-pubescent, especially upon the inflorescence, with more acuminate incisely toothed leaflets, the umbellets involucellate, and the fruit larger. A. ARGUTA, Nutt., reported by him from Vancouver Island, has not since been collected. It is described as glabrous, with small ovate rather acute leaflets and large oblong-elliptical fruit. *A.* (?) *verticillata*, Hook., judging from the description given, probably belongs to some other genus.

LONICERA UTAHENSIS, Watson. It appears probable that the single flower collected with the original specimens, upon whose characters the species was chiefly based, was an abnormal one. Otherwise the species closely resembles *L. ciliata*, but differs in its more oblong and always obtuse leaves. It ranges from Southern Utah to Northwestern Montana and Northern Idaho, and to the Blue Mountains of Oregon, and includes all the so-called *L. ciliata* of that region.

Douglasia dentata. Rather stout, branching, canescent with a fine mostly dense pubescence: leaves rosulate at the nodes, thick, oblong, obtusish, mostly with 1 to 3 blunt teeth on each side toward the summit, 4 to 6 lines long: peduncle (an inch long) bearing a simple few-flowered umbel; pedicels very unequal (2 to 12 lines long): calyx narrowed at base, 3 lines long in fruit, the acuminate lobes nearly as long as the tube: capsule oblong, slightly stipitate, equalling the calyx-tube. — In the Cascade Mountains, on a dry ridge above Peshaston Cañon, Yakimah County, Washington Territory; collected by myself, in fruit, October, 1880. Near *D. lævigata*, Gray.

Pedicularis Furbishiæ. Stem simple or sparingly branched, leafy, pubescent, about 3 feet high: lower leaves on slender petioles, more or less completely pinnate, with pinnatifid segments, the upper sessile and pinnatifid; lobes acutely toothed, slightly white-margined; bracts very broadly ovate, cuneate at base, irregularly laciniate: calyx short (3 or 4 lines long), the five lanceolate teeth usually laciniate at the apex; corolla greenish yellow, narrow, 8 lines long, the suberect galea a little exceeding the lip, its cucullate summit truncate and often shortly bicuspidate: capsule ovate, oblique, about equalling the calyx: seeds oblong-ovate, flattened and somewhat wing-margined, the testa loose, light-colored, and finely rectangular-pitted. — On wet banks of the St. John's River, at Van Buren, Arostook County, Maine, and extending along the river for sixty miles. Dedicated to its discoverer, Miss Kate Furbish, whose careful study of the flora of her State, and perseverance and success in illustrating it by colored drawings of all the species, richly deserve an appropriate recognition. The species is allied to *P. Canadensis* and *P. bracteosa*. It may be worth the while to note the differences in the seeds of these species, which in *P. Canadensis* are ovate and turgid, with a close thin brownish testa, and in *P. bracteosa* are oblong, somewhat concavo-convex, and with 3 to 5 strong corky longitudinal ribs.

Mirabilis tenuiloba. Viscid-pubescent, and resembling *M. Californica*, from which it may be distinguished by its more acute or somewhat acuminate cordate leaves, and by the larger involucre (4 or 5 lines long), cleft to or below the middle, the segments narrowly lanceolate. — In San Bernardino County, California; W. G. Wright, 1880.

Oxybaphus linearifolius. Slender, 2 feet high, with spreading branches from alternate axils, glabrous excepting the pubescent peduncles, involucres and flowers: leaves linear, attenuate to the base, the lower 3 or 4 inches long: peduncles very slender, spreading or reflexed, 2 to 4 lines long: involucre 1–2-flowered, becoming 6 lines broad, cleft to below the middle, the lobes acute or acuminate: perianth greenish, campanulate, 2 or 3 lines long: stamens 5: fruit oblong-obovate, pubescent, very prominently 5-costate, the costæ very thick and nearly contiguous. — Plains near Apache Pass, in the Chiricahua Mountains, Arizona; J. G. Lemmon, 1881. Resembling forms of *O. nyctagineus*, but more slender and with more leafy and less pubescent inflorescence, the more deeply and acutely lobed involucre with fewer flowers, and the fruit more prominently ribbed.

BOERHAAVIA PTEROCARPA. Annual, branching from the base, scabrous-puberulent, a foot high or less: leaves ovate to oblong-lanceolate, obtuse or acutish, cuneate at base, entire or somewhat sinuate-toothed, $\frac{1}{2}$ to 1 inch long: peduncles axillary and terminal, short, bearing an umbel of 3 to 6 white or pinkish flowers: fruit obpyramidal, attenuate to the very short pedicel, truncate, 3–5-sided and winged at the angles, the sides transversely rugose. — At Apache Pass, Arizona; J. G. Lemmon, 1881. Remarkable for its winged fruit.

AMARANTUS (AMBLOGYNE) VENULOSUS. Diœcious, nearly glabrous, erect, branching, leafy, 1 to 3 feet high: leaves linear-lanceolate, attenuate to a slender petiole, the blade 1 or 2 inches long: pistillate flowers in close axillary glomerate panicles; sepals twice longer than the single small ovate acute bract, becoming thickened at the rather narrow base, broadly dilated and rounded above, entire or emarginate or somewhat denticulate, and marked with green veins: seed $\frac{1}{3}$ of a line broad. — Collected by Thurber at Santa Cruz, Sonora (*Sarratia Berlandieri*, var. *denticulata*, Torr. in Bot. Mex. Bound. 179), and in Rucker Valley and Apache Pass, Arizona, by J. G. Lemmon, 1881. Staminate plants not seen.

ACNIDA (MONTELIA) FLORIDANA. Annual, tall and slender, diffusely branched: leaves linear to narrowly lanceolate, attenuate to a slender petiole: spikes elongated and very slender, interrupted; bracts short (scarcely $\frac{1}{2}$ line long), acute or shortly acuminate: utricle very thin, angled and somewhat tuberculate, at length bursting irregularly: seeds black and shining, obtusely margined, $\frac{2}{3}$ of a line broad. — At Key West (Blodgett), on the sandy coast at North Clear Water Pass (Chapman), and in Southern Florida also by Dr. Garber and A. H. Curtiss. *A. tuberculata*, Gray, differs in its stouter habit, larger and broader leaves, closer and stouter spikes, and longer and more attenuate acuminate bracts.

CLADOTHRIX OBLONGIFOLIA. Stems procumbent, often 2 feet long, the branches ascending, and the whole plant covered with a very dense persistent white stellate pubescence: leaves ovate-oblong or oblanceolate, attenuate to a slender or short petiole, acutish: flowers clustered, white. — On the banks of the Colorado, near Chimney Peak (Dr. Newberry) and at Yuma (C. G. Pringle), and in the Mohave Desert (S. B. & W. F. Parish). Differing from *C. lanuginosa*, Nutt. (to which Newberry's specimen is referred in Ives' Report and in the Botany of California), in its less prostrate habit, denser and more persistent pubescence, narrower leaves more attenuate at base, and rather smaller and paler flowers.

Atriplex orbicularis. Monœcious, perennial and somewhat woody at base, 3 to 4 feet high, subcanescent with very fine pubescence: leaves alternate, oblong-obovate, an inch long or more, retuse or obtuse and apiculate, attenuate to a very short slender petiole: inflorescence paniculate, naked or leafy below, the small dense staminate clusters with the pistillate flowers and in slender terminal moniliform spikes; pistillate flowers in sessile clusters: fruiting bracts herbaceous, thin, orbicular and compressed, somewhat coherent toward the base, entire, not appendaged on the back, 2 or 3 lines in diameter: ovary sessile; styles included: seed ½ line broad: radicle superior. — At Santa Monica, California, on the sea-shore at the base of the bluffs; S. B. & W. F. Parish, October, 1881. A strongly marked species, much resembling *A. hortensis*, from which it is separated especially by the dense heads of larger male flowers, the sessile ovary, and superior radicle.

Atriplex Parishii. Monœcious, annual (?), prostrate, diffusely branched and leafy throughout, the slender stems woolly-pubescent, 6 to 10 inches long: leaves alternate, farinose, small (2 lines long or less), sessile, ovate, acutish: pistillate and staminate flowers together, usually a pair of each in each axil; calyx 4-parted; bracts triangular-hastate, becoming 1½ lines long in fruit and somewhat rigid, the toothed lobes and acutish apex herbaceous: styles long and exserted: seed black, ½ line broad: radicle superior. — Costa Station, Los Angeles County, California, in alkaline soil; S. B. & W. F. Parish, October, 1881. Of the *A. patula* group.

Atriplex fasciculata. Monœcious, annual, branching from the base, scurfy-pubescent throughout, the ascending leafy stems 6 inches high or less: leaves alternate, oblanceolate, sessile, entire, obtuse or acutish, 3 to 5 lines long: flowers fascicled in all the axils, the staminate very small and mingled with the pistillate; fruiting bracts orbicular, compressed and coherent, very nearly sessile and often deflexed, nearly 1½ lines broad, not appendaged upon the back, the narrow herbaceous margin minutely and mostly bluntly toothed. — Near Fish Ponds, Mohave Desert; S. B. & W. F. Parish, May, 1882. Resembling *A. elegans*, but the fruiting bracts much less conspicuously toothed.

Atriplex Parryi. Diœcious (?), perennial and woody, much branched and with rigid spinosely tipped slender divaricate leafy branchlets, white-scurfy throughout: leaves thick, sessile, cordate or broadly ovate, acute, 2 to 4 lines long: pistillate flowers 1 to 4 in the axils; bracts sessile, united below into a compressed-campanulate sac, becoming thick and rigid, bordered above by the broader rounded free margins, the whole about 1½ lines long in fruit and the margins somewhat more in breadth. — Near Colton, California; Dr. C. C. Parry, 1881. Resembling *A. confertiflora*, but with much smaller fruiting bracts, and their margins more broadly dilated in proportion.

Kochia Californica. Silky-pubescent and subtomentose throughout, much branched and the branches divergent: leaves linear-oblong, 5 to 6 (on the branches 2 to 4) lines long, about a line broad: flowers 1 to 5 in the axils, the calyx developing a wing about 3 lines broad. — Southern California; near Colton (C. C. Parry, 1881), and at Rabbit Springs, San Bernardino County (S. B. & W. F. Parish, May, 1882). Readily distinguished from *K. Americana* by its more diffusely branched habit and its proportionately broader leaves.

Polygonum (Avicularia) intermedium, Nutt., in herb. Annual, glabrous or somewhat rough-puberulent, much branched from the base, the slender reddish quadrangular branches decumbent or procumbent, a foot long or less: leaves linear-lanceolate, acute, ½ to 1 inch long; the acuminate triangular sheathing stipules entire or finally lacerate: flowers axillary and in leafy-bracteate spikes, small (a line long or less), rarely reflexed in fruit: stamens 8. — On bluffs of the Columbia River, Oregon; C. G. Pringle, October, 1881, and by Nuttall, probably in the same region. Resembling *P. coarctatum*, but with much smaller flowers.

Eriogonum (Ganysma) apiculatum. Annual, slender, somewhat branched from the base, a foot high, nearly glabrous, the branches slightly glandular: leaves all radical, slightly hispid, spatulate, 1½ inches long: pedicels slender, spreading, 2 or 3 lines long, or the alar erect and longer: involucres turbinate-campanulate, nearly a line long: flowers nearly glabrous, pinkish, a line long, the outer segments obcordate, the inner oblong-obovate and emarginate, all apiculate in the sinus. — On the San Jacinto Mountains, at about 9,000 feet altitude; Parish Brothers, July, 1881. Of the *E. trichopodum* group.

Eriogonum Parishii. Of the same group, and resembling the last in its foliage, glaucous, somewhat viscid with mostly stipitate glands, the 2 or 3 stems very diffusely branched above the first node, about a span high: pedicels very slender, spreading, 1 to 3 lines long: involucres turbinate-campanulate, $\frac{1}{3}$ of a line long or less: flowers very small ($\frac{1}{4}$ line long), red, minutely pubescent, the outer segments oblong-lanceolate, acute, the inner broadly oblong-spatulate and shortly apiculate. — Collected in the San Bernardino Mountains, also by the Parish Brothers, in August, 1881.

Eriogonum (Oregonium) delicatulum. Of the § *Corymbosa*, annual, very slender, low (3 to 5 inches high), glabrous above the base: leaves radical, tomentose, round to oblong, 1 to 3 lines long, with slender petioles: involucres narrowly turbinate, obscurely nerved, a line long: flowers yellow, very small: akene soon exserted, a half longer than the perianth. — In the Mohave Desert; Dr. C. C. Parry, 1881. Resembling *E. Mohavense*, but smaller and more slender, with narrower and less strongly nerved involucres, and the akenes exserted.

Eriogonum molestum. Resembling *E. virgatum*, slender, glabrous excepting the leaves, 1 to 3 feet high: leaves all radical, reniform to cordate or rounded, densely white-tomentose at least beneath, about an inch broad: involucres few and distant, rarely 2 or 3 together, 2 to 3 lines long: flowers white or pinkish. — Apparently frequent in the mountains of Southern California, from Los Angeles County to San Diego; collected by Palmer, D. Cleveland, Parish Brothers, Rev. J. C. Nevin, &c.

Chorizanthe cuspidata. Prostrate, villous-pubescent, with leafy bracts: leaves narrowly oblanceolate, an inch long or less: floral bracts acerose: involucres numerous, loosely cymosely clustered, a line long, 6-toothed, without scarious margins, the alternate teeth shorter, and all armed with hooked awns: flower nearly sessile, villous, pinkish; lobes oblong, nearly equal, acutish, strongly nerved and the nerve excurrent as a short cusp. — Near San Francisco; Marcus E. Jones, 1881 (n. 2386). Allied to *C. Parryi*.

Corallorhiza Arizonica. Stem stout ($1\frac{1}{2}$ feet high), with 6 to 8 short sheathing leaf-scales, 10–15-flowered: flowers large, spurless and scarcely at all gibbous, the sepals and petals (6 to 8 lines long) several-nerved; lip dilated and strongly nerved, with 5 prominent ridges down the centre, 3-lobed above, the middle lobe undulate on the margin and somewhat cucullate: column a third shorter than the sepals, narrowly margined: capsule 6 to 8 lines long, narrowed to a pedicel about equalling the bract. — In rocky places on the Santa Rita Mountains, Arizona; C. G. Pringle, July, 1881. Peculiar in the very slight gibbosity of the perianth, and in the number of ridges and strong veining of the lip.

Cypripedium fasciculatum, Kellogg, in herb. Dwarf (2 to 6 inches high), the villous-pubescent stem scariously sheathed at base and bearing a pair of nearly opposite ovate acutish leaves (2 to 4 inches long): peduncle viscid-pubescent, ½ to 1½ inches long, with a small lanceolate bract in the middle: flowers solitary, or usually several in a terminal cluster, bracteate, greenish: sepals and petals lanceolate, acuminate, 6 to 8 lines long, brown-veined, the lower sepals wholly united or very nearly so; lip depressed-ovate, greenish-yellow with brown-purple margin, 4 or 5 lines long: sterile anther oblong, obtuse, equalling the stigma. — Collected by W. N. Suksdorf on the White Salmon River, Washington Territory, above the falls, in May, 1880; by Mrs. R. M. Austin in May, 1881, near Prattville, Plumas County, California; and at some time previous by Mr. Bradley, probably in the mountains of Del Norte County. Resembling *C. guttatum*, of Alaska.

Iris tenuis. Rootstock very slender (a line or two thick): stems 8 to 10 inches high, with 2 or 3 bract-like leaves 2 or 3 inches long, 2-flowered; the longer leaves of the sterile branches of the rootstock equalling the stems and 4 to 6 lines broad: bracts contiguous, the longer about equalling the slender peduncles (2 to 4 inches long): flowers "white, lightly striped and blotched with pale yellow and purple;" perianth-tube 2 or 3 lines long, the segments naked, slightly spreading, oblong-spatulate, the outer 15 lines long, a little exceeding the emarginate inner ones: ovary 3 lines long. — Discovered by L. F. Henderson in 1881 on Eagle Creek, a branch of the Clackamas River, Oregon.

Allium Brandegei. Bulbs small, the reticulation of the coats horizontally oblong (as in *A. anceps*): leaves 2, exceeding the angular scape, 4 inches long by 1 or 2 lines wide: pedicels slender, equal, about 4 lines long: flowers rose-colored, the broadly lanceolate acute segments 3 or 4 lines long, nearly twice longer than the stamens: ovary not crested. — A pretty species, of the *A. Douglasii* group, found by T. S. Brandegee in the Elk Mountains, Colorado, where he reports it to be frequent.

Allium Parishii. Bulbs with numerous reddish-brown coats, without reticulation (or rarely minute and transversely short-oblong): scape rather stout, 4 to 6 inches high, with a single sheathing linear elongated leaf: spathe-valves 2, broadly ovate: pedicels few (6 to 12), short and stout: petals bright rose-color, 6 to 8 lines long, lanceolate, acuminate, twice longer than the stamens: filaments lanceolate: crests prominent, acutish, irregularly toothed: stigma somewhat lobed. — In the mountains bordering the Mohave Desert, near Cushenberry Springs; Parish Brothers, May, 1882. A showy species of the *A. cristatum* group, with unusually large flowers.

BRODIÆA STELLARIS. Resembling *B. minor*: leaves nearly terete: stems 2 to 6 inches high, from small fibrous-coated bulbs, bearing a 3–6-flowered umbel; pedicels unequal, very short: perianth narrow at base, 6 to 10 lines long, the greenish tube nearly equalling the deep-purple segments: filaments very short, winged on each side, the broadly oblong appendages half the length of the anther, which is 1½ lines long and shorter than the white deeply emarginate staminodia: ovary attenuate to a short stipe, acute, the cells 6–8-ovuled: capsule nearly equalling the perianth. — On high mountain sides near Ukiah, Mendocino County, California; collected by Mr. Carl Purdy, in June, 1881, who suggests the name with reference to the radiate appearance of the scapes and pedicels. Distinguished by the winged filaments, which resemble the corresponding ones of *B. capitata*.

BRODIÆA FILIFOLIA. Leaves very narrow (½ line broad or less), about equalling the scape (a span high): pedicels unequal, ¼ to nearly 2 inches long: perianth 6 to 9 lines long, the broadly oblong segments exceeding the rather narrow tube, the outer segments mucronate: anthers 3, sessile, somewhat sagittate at base, 2 lines long, nearly twice longer than the triangular staminodia: ovary sessile; cells 2-ovuled: capsule oblong-obovate, 3 lines long. — Collected near San Bernardino by S. B. & W. F. Parish, in 1880, as also by G. R. Vasey. Distinguished by the short staminodia.

CALOCHORTUS LONGEBARBATUS. Stem slender, nearly a foot high, bulbiferous near the base, with 1 or 2 narrow radical leaves, 2-branched and usually 2-flowered at the summit: pedicels erect in flower and fruit, or nearly so: petals lilac, yellowish at base, an inch long, obovate, erose-denticulate at the rounded summit, with a broad glandular pit bordered above by very long flexuous hairs, otherwise nearly naked: anthers narrowly oblong, obtuse, nearly 2 lines long: capsule broadly ovate and winged, 6 to 10 lines long. — In low grassy grounds, Falcon Valley, Klickitat County, Washington Territory; W. N. Suksdorf, July, 1881. Allied to *C. nitidus*.

TRADESCANTIA FLORIDANA. Stems very slender, procumbent and matted, rooting at the lower joints, glabrous: leaves ovate-lanceolate, acute, 8 to 10 lines long, thin and glabrous, minutely ciliolate, the scarious sheaths narrow and ciliate: peduncles usually terminal, 1 or 2, glabrous; umbel 3–8-flowered, involucrate with small ovate or lanceolate bracts; pedicels glandular-pubescent, 1 to 3 lines long: sepals slightly pubescent, purplish, a line long, a little shorter than the white petals: filaments naked; anther-cells closely contiguous: style stout, as long as the oblong-ovate ovary. — In damp shade, Central Florida, in St. John's and Sumter Counties, &c., collected by Miss Mary C. Reynolds, in 1878, and by J. Donnell Smith and A. H. Curtiss. Referred to *T. gracilis*, HBK., by C. B. Clarke in his revision of the order, from which it is clearly distinct, that species having bearded filaments and anther-cells widely separated upon a broad arcuate connective, broad and densely ciliate sheaths, rougher leaves, &c.

CYPERUS SERRULATUS. Perennial, a foot high or less, the smooth stem exceeding the flat rough-edged leaves: involucral bracts 3 or 4, very scabrous-serrulate on the margin, mostly exceeding the subcapitate umbel: spikelets numerous, on very short rays, linear-oblong, 4 to 12 lines long, the spreading greenish acute scales flattened and acutely carinate, not decurrent on the rhachis, the keel serrulate toward the apex: nutlet triangular, oblanceolate, acutish, narrowing downward to a substipitate base, $\frac{1}{2}$ line long. — Received from Dr. George Vasey as collected in Placer County, California, in October, 1880.

PROCEEDINGS.

Seven hundred and forty-second Meeting.

May 24, 1881. — ANNUAL MEETING.

The PRESIDENT in the chair.

The Treasurer and Librarian presented their annual reports.

The following gentlemen were elected members of the Academy: —

Alvan Graham Clark, of Cambridge, to be a Resident Fellow in Class I., Section 2.

Francis Blake, of Auburndale, to be a Resident Fellow in Class I., Section 3.

Lucien Carr, of Cambridge, to be a Resident Fellow in Class III., Section 2.

Fordyce Barker, of New York, to be an Associate Fellow in Class II., Section 4.

John Shaw Billings, of Washington, to be an Associate Fellow in Class II., Section 4.

Jacob M. DaCosta, of Philadelphia, to be an Associate Fellow in Class II., Section 4.

Alfred Stillé, of Philadelphia, to be an Associate Fellow in Class II., Section 4.

Manning Ferguson Force, of Cincinnati, to be an Associate Fellow in Class III., Section 3.

William Graham Sumner, of New Haven, to be an Associate Fellow in Class III., Section 3.

William Stubbs, of Oxford, to be a Foreign Honorary Member in Class III., Section 3, in place of the late Thomas Carlyle.

The annual election resulted in the choice of the following officers: —

JOSEPH LOVERING, *President.*
OLIVER W. HOLMES, *Vice-President.*
JOSIAH P. COOKE, *Corresponding Secretary.*
JOHN TROWBRIDGE, *Recording Secretary.*
THEODORE LYMAN, *Treasurer.*
SAMUEL H. SCUDDER, *Librarian.*

Council.

WOLCOTT GIBBS,
EDWARD C. PICKERING,
CHARLES W. ELIOT, } of Class I.

HENRY W. WILLIAMS,
GEORGE L. GOODALE,
HENRY P. BOWDITCH, } of Class II.

FRANCIS J. CHILD,
CHARLES G. LORING,
EDWARD ATKINSON, } of Class III.

Rumford Committee.

GEORGE B. CLARK. JOSEPH LOVERING,
JOSIAH P. COOKE, JOHN M. ORDWAY,
WOLCOTT GIBBS, EDWARD C. PICKERING,
JOHN TROWBRIDGE.

Member of Committee of Finance.

THOMAS T. BOUVÉ.

On the motion of the Corresponding Secretary it was

Voted, That when this meeting adjourn, it adjourn to the second Wednesday in June next.

The following papers were presented by title: —

"The Spectrum of Arsenic." By O. M. W. Huntington.

"Researches on the Compound Inorganic Acids." Paper No. 3. By Wolcott Gibbs.

"Spectra of Celestial Objects." By Edward C. Pickering.

Seven hundred and forty-third Meeting.

June 8, 1881. — ADJOURNED ANNUAL MEETING.

The PRESIDENT in the chair.

The President appointed the following standing committees: —

Committee of Publication.

ALEXANDER AGASSIZ, JOSIAH P. COOKE,
JOHN TROWBRIDGE.

Committee on the Library.

HENRY P. BOWDITCH, WILLIAM R. NICHOLS.
EDWARD C. PICKERING.

Auditing Committee.

HENRY G. DENNY, ROBERT W. HOOPER.

The Chairman of the Rumford Committee presented the following Annual Report: —

"During the last year (May 1880–May 1881) investigations have been made by members of the Committee, individually or collectively, on the Magnetizing and Demagnetizing of Metals; on Atmospheric Refraction; on the Dynamo-electric Machine; and by Professor Langley on Radiant Energy, with his new instrument, the Bolometer. Mr. Edmands has been employed to do some additional work on the measurements of Rutherfurd's Photographic Spectrum, and on a comparison of observations with the spectrometer.

"The Committee have authorized the payment by the Treasurer of the following sums out of the income of the Rumford Fund: —

To Professor Trowbridge for apparatus, &c., for magnetic experiments, ...	$97 65
To Dr. Gibbs for a new dynamo-machine, . . .	115 86
To Professor Langley for apparatus, &c., . . .	300 00
To Mr. Edmands for work on Rutherfurd's photograph, ...	4 31
To Mr. Edmands for work on spectrometer, . .	30 00
To Philadelphia Mint for medals (including engraving and case), ...	359 79
To Mr. Edmands for work on Atmospheric Refraction, ...	24 36
Total, ...	$931 97

"The Committee have also authorized the payment from the Rumford Fund of that portion of Mr. Wilson's bill, amounting to $286.23, which is charged for the printing of the papers 1, 2, 7, 10, 13, 18, 21, and 22, in Volume XVI. of the Proceedings of the Academy, these being on subjects connected with Light or Heat; and also the payment of $400.00, at the order of the Librarian, for the purchase of books on Light or Heat.

"Respectfully submitted,

"JOSEPH LOVERING, *Chairman*.

"BOSTON, June 8, 1881."

In accordance with the recommendation of the Rumford Committee, one thousand dollars ($1000) were appropriated from the income of the Rumford Fund for investigations on Light and Heat during the current year.

On the motion of the Treasurer it was

Voted, to appropriate: —

For publishing Proceedings, ...	$1100
For publishing Memoirs, ...	900
For Books and Binding, ...	1250
For General Expenses, ...	2200
	$5450

The following paper was presented by title: —

"Eclipses of Jupiter's Satellites." By Edward C. Pickering.

Seven hundred and forty-fourth Meeting.

June 22, 1881. — SPECIAL MEETING.

The PRESIDENT in the chair.

The Corresponding Secretary read the following letter: —

"MASSACHUSETTS CHARITABLE MECHANIC ASSOCIATION,
"OFFICE OF THE PRESIDENT, BOSTON, June 9, 1881.

"PROFESSOR JOSIAH P. COOKE.

"DEAR SIR, — I have the honor to request, in behalf of the Board of Managers of the Fourteenth Exhibition of the Massachusetts Charitable Mechanic Association, that the Fellows of the American Academy of Arts and Sciences should do them the honor to bestow, this fall, the Association's 'Grand Medal,' for that single exhibit in the ensuing display most conducive to human welfare.

"Such medal will be established by the Association, and we are desirous of its bestowment in a manner that will add to its value; and it has seemed to our Board of Managers that no more renowned or impartial body could be selected than the Academy which you represent.

"Should this suggestion meet the approval of your Associates, and the duty be undertaken by your body, I shall be very happy to confer further with you in regard to the matter.

"I am, very respectfully,
"Your obedient servant,
"CHARLES W. SLACK,
"*President.*"

On the motion of Professor Cooke it was

Voted, To appoint a Committee of seven Fellows of the Academy who, after conferring with the authorities of the Charitable Mechanic Association, shall have full power to decide whether it is advisable for the Academy to accept the proposed trust, and shall report their decision or action to the Academy at their stated meeting in October.

The President appointed the following Committee in accordance with this vote: —

Theodore Lyman, *Chairman.*

Henry P. Bowditch, Edward C. Pickering,
Wolcott Gibbs, John Trowbridge,
Hiram F. Mills, Charles H. Wing.

Seven hundred and forty-fifth Meeting.

October 12, 1881. — Stated Meeting.

The President in the chair.

Letters in acknowledgment of election were received from Messrs. F. Blake, Billings, Brown-Séquard, Da Costa, Force, Stillé, Stubbs, and Sumner.

Mr. Lyman presented an informal Report from the Committee on the "Grand Medal" of the Massachusetts Charitable Mechanic Association, which, in substance, was that the Committee had found certain exhibits which seemed to warrant the conferring of such a medal.

On the motion of Mr. Scudder it was

Voted, That the Report of the Committee be accepted, and that the Academy undertake the responsibility which the Charitable Mechanic Association desires to impose upon it; also,

Voted, That the Committee on the "Grand Medal" continue their work, and present their final Report at the next meeting of the Academy.

The following gentlemen were elected members of the Academy: —

Clarence John Blake, of Boston, to be a Resident Fellow in Class I., Section 3.

Thomas Gaffield, of Boston, to be a Resident Fellow in Class I., Section 3.

Frederic Walker Lincoln, of Boston, to be a Resident Fellow in Class I., Section 4.

William Otis Crosby, of Boston, to be a Resident Fellow in Class II., Section 1.

William Harmon Niles, of Cambridge, to be a Resident Fellow in Class II., Section 1.

Charles Rockwell Lanman, of Cambridge, to be a Resident Fellow in Class III., Section 2.

John Davis Long, of Hingham, to be a Resident Fellow in Class III., Section 2.

John Cummings, of Woburn, to be a Resident Fellow in Class III., Section 3.

Henry Draper, of New York, to be an Associate Fellow in Class I., Section 2.

The following paper was presented: —

"On the Co-efficient of Expansion of a Bar of Tempered Steel which has its Graduated Surface protected by a Covering of Thin Glass." By William A. Rogers.

Voted, That when the Academy adjourn, it adjourn to the second Wednesday in November, and that that meeting be an Adjourned Stated Meeting.

Seven hundred and forty-sixth Meeting.

November 9, 1881. — ADJOURNED STATED MEETING.

The PRESIDENT in the chair.

Letters were read from Messrs. C. J. Blake, Draper, Gaffield, Lanman, and Long, acknowledging their election into the Academy.

The chair announced the death of Mr. John A. Lowell.

Mr. Theodore Lyman read the

Report of the Committee on the "Grand Medal" of the Massachusetts Charitable Mechanic Association.

"The judges first agreed that the exhibit for the grand award must possess invention not only original but novel, because the admission of old inventions to competition would render the task of selection hopelessly complicated, and because such admission would be against the intention of the Association which offered the Medal. In order to get a knowledge of the contents of the Exhibition, the manuscript catalogue was examined, and all exhibits that might be candidates were noted and inspected. There was also distributed to the exhibitors the following circular: —

"'*The Grand Gold Medal.* — Boston, Oct. 6, 1881. — The Committee appointed by the American Academy of Arts and Sciences to consider the award of a Grand Medal, by the Massachusetts Charitable Mechanic Association, "for the single exhibit most conducive to human welfare," wish to obtain information for their guidance. If you desire to compete for this Medal, please to state your claims by filling the following blanks: —

"'1. Date of patent and time of introduction.

"'2. Brief description of the exhibit, with a statement of the reasons of its superiority, and of its contribution to human welfare.

"'Replies should be directed, before October 20, to Theodore Lyman, Chairman, American Academy of Arts and Sciences, Boston.'

"The circulars returned were read and considered. When, by gradual elimination, the candidates had been reduced to three or four, special reports were prepared on them, and these reports were discussed at a meeting of the Committee. A ballot was then taken, which resulted in the selection, by a unanimous vote, of the exhibit of results of the 'testing machine,' now at the United States Arsenal in Watertown, and designed and constructed by Mr. Albert H. Emery (a civil engineer), as the 'single exhibit most conducive to human welfare,' and therefore the proper one to receive the Grand Medal.

"The purpose of the testing machine is to show the effect of a given push or a given pull on any solid material. The specimen, placed horizontally, is squeezed or pulled at pleasure, and the power at work is measured in two forms: —

"1. The force used to hold the specimen in place, and that exerted in the straining press, is indicated by a gauge.

"2. The strain on the specimen is shown by a weighing apparatus.

"Considered purely as a testing machine, it is the latter apparatus only which is directly important; but viewed as a construction capable of several uses (which uses are claimed by the inventor), the first contrivance or gauge becomes of consequence, because it can be applied to measure with accuracy many sorts of pressure, such as that of steam or that of the air. In like manner the weighing apparatus may, *mutatis mutandis*, be used as a delicate scale.

"It would not be proper to give a detailed description of the structure, because there are patents on certain portions of it that are not yet secured; but a general sketch of it is admissible.

"This testing machine was ordered in June, 1875, by the United States Board on the Testing of Iron and Steel, of which Colonel T. T. S. Laidley, U. S. A., was chairman. It was completed about three years ago. The first patent was in 1872, and others have since been granted or are now pending. The machine has as its source of pressure a hydraulic accumulator; and by this pressure the specimen is held in place, and a steady and easily controlled strain is imparted to it through a hydraulic press.

"This straining press has a double action, which, in connection with the alternating bed and platform of the scale, allows a test, either by compression or tension, without the addition of intervening parts. The strain upon the specimen is transmitted directly and without friction to liquid supports capable of receiving a strain of 1,000,000 pounds, without exceeding the safe limit of strain for diaphragms intended for perpetual use.

"The pressure in these liquid supports is communicated, without loss and with great sensitiveness, to other supporting chambers acting directly, and still without friction, through a single pair of levers having steel-plate fulcrums. These last, as distinguished from knife-edge fulcrums, are not subject to injury from load or shock; may be protected from corrosion; allow a free movement of the beam; may be adjusted exactly; and are durable, since their motion is molecular and far within the limits of elasticity. By means of similar fulcrums, the strain — now reduced — is communicated to the scale beam, and motion is imparted to the indicator rod, where a variation of a single pound is distinctly visible, if the load be small; and for the maximum load of 1,000,000 pounds, a variation of $\frac{1}{250,000}$, or four pounds, may be noted; while by an admirable system of levers the total weight is recorded on an indicator plate. The specimen tested may even be thirty feet in length, — a limit which would include many built-up structures, such as columns, trusses, and bridge spans.

"Among the proof experiments to which this machine was subjected by the United States Board, the following may be quoted: —

"1. A forged link of hard wrought iron, five inches in diameter between the eyes, was slowly strained in tension, and broke short off with a loud report at 722,800 pounds.

"2. In order to see if the weighing parts had been disturbed by the recoil, which was obviously near the greatest recoil the machine will ever suffer, a horsehair was next tested. It was $\frac{7}{1000}$ of an inch in diameter, it stretched thirty per cent, and broke at one pound.

"3. Specimens were subjected to 1,000,000 pounds compression.

"4. Delicate structures, such as eggs and nuts, were tested in compression.

"The results of these and of many other proof experiments demonstrate the efficiency of this testing machine. Its action as a whole does not end its usefulness, for its separate parts may be adapted to other modes of testing. It is evident, for example, that the bed and platform, with the four supporting chambers, could be removed and built in as one of the arch stones in a great arch, where the pressure at that point would be indicated by the scale beam, and by a slight modification of the connections, there might be shown the position of the resultant line of pressure under either a still or a moving load. Were the same parts buried in the rear of a retaining wall, they would measure the thrust; and the effect of that thrust would be shown if they were built into the lower course of that wall.

"The gauges in this machine which measure the pressure on the specimen holders, and that in the straining press, constitute in themselves a very promising form of steam gauge. As they stand, they are capable of indicating from one pound to the square inch to 3,600 pounds, without straining any part beyond the safe limit of elasticity. The need of an accurate steam gauge which will not degenerate is illustrated by the fact that the United States Board appointed to study the causes of the bursting of steam boilers reported that its results were entirely unreliable, because no steam gauge could be found on which dependence could be placed.

"It only remains to indicate in what way and to what degree the testing machine is conducive to human welfare.

"It lessens the risk of life and the cost of construction, by condemning every dangerous part and exposing each excess of material. Structures may have various faults: (1) They may be too weak, and therefore liable to give way at all points. (2) They may be strong enough in some parts but weak in others, where they are ready to break. (3) They may be everywhere too strong, in which case the weight of useless material must be subtracted from the load they ought to bear. In the first instance, the structure is dangerous and too cheap; in the second, it is dangerous and in certain places too cheap; in the third, it is dangerous (because overweighted) and too costly. Only by such an instrument as a testing machine can these faults be avoided.

"Our mode of life is highly artificial, and is daily growing more so. We are everywhere dependent on machinery and on complex structures, be they railroads, steamboats, manufactories, or great public buildings. These things are absolutely necessary, and make the foundation of human happiness; but they bring corresponding perils, so that a community which has bad public works lives in constant danger. Such danger has hitherto been considerable, even in presence of the best precautions, because there were no means for accurately determining the strength of the materials employed. But with this testing machine there can no longer be an excuse for materials weak in themselves, or improperly proportioned. By its use every part may be made safe, from the simple rail to the most complex bridge, from the humble hand-car to the largest locomotive, and from the plain column to the most elaborate trussed roof.

"A machine which can guarantee the safety of most of our artificial surroundings may properly be called conducive to human welfare.

"THEODORE LYMAN,
EDWARD C. PICKERING,
CHARLES H. WING,
JOHN TROWBRIDGE,
HIRAM F. MILLS,
HENRY P. BOWDITCH."

The Report of the Committee was accepted. A vote was then taken, which resulted in the selection, unanimously, of the exhibit of results of the testing machine now at the United States Arsenal in Watertown, and designed and constructed by Albert H. Emery, civil engineer, as the "single exhibit most conducive to human welfare," and therefore the proper one to receive the Grand Medal of Honor.

Luigi Palma di Cesnola, of New York, was elected an Associate Fellow in Class III., Section 4.

The following papers were read: —

"On the Scientific Use of the Telephone." By John Trowbridge.

"On a Machine for Reproducing and Transmitting Vowel and Consonant Sounds." By Amos E. Dolbear.

The following paper was presented by title: —

"On Indirect Determination of Chlorine and Bromine by Electrolysis." By Leonard P. Kinnicutt.

Seven hundred and forty-seventh Meeting.

December 14, 1881. — MONTHLY MEETING.

The PRESIDENT in the chair.

The President informed the Academy that a letter had been received from General L. P. di Cesnola, acknowledging his election as Associate Fellow; also a letter announcing the death of Herr Geheimerath J. C. Bluntschli, D.C.L., of Heidelberg, Foreign Honorary Member.

The following papers were presented: —

"On Curcumin." By C. L. Jackson and A. E. Menke.

"A Comparison of the Harvard College Observatory Catalogue of Stars for 1875 with the Fundamental Systems of Auwers, Boss, Safford, and Newcomb." By William A. Rogers.

"On Maxwell's Law of the Distribution of Energy among the Molecules." By N. D. C. Hodges.

Professor Wolcott Gibbs announced his discovery of the following new complex acids: —

Arsenoso-molybdic acid,
Arsenoso-tungstic acid,
Antimonoso-molybdic acid,
Antimonoso-tungstic acid,
Vanadoso-molybdic acid.
Vanadoso-tungstic acid,
Vanadoso-phosphoric acid,
Vanadoso-arsenic acid,
Vanadoso-antimonic acid,

All these acids have well-defined series of salts.

Seven hundred and forty-eighth Meeting.

January 11, 1882. — STATED MEETING.

A quorum was not present, and the Academy was not called to order.

Seven hundred and forty-ninth Meeting.

February 8, 1882. — MONTHLY MEETING.

The PRESIDENT in the chair.

The chair announced the following deaths: —

Lewis Henry Morgan, Dec. 17, 1881; Edward Reynolds, Dec. 25, 1881; John William Draper, Jan. 4, 1882; Richard Henry Dana, Jan. 6, 1882; Theodor Schwann, Jan. 11, 1882.

The following papers were presented: —

"On a New Telephone." By A. E. Dolbear.

"Conventionalism in Ancient American Art, Illustrated by Specimens of Pottery from the Burial Mounds." By F. W. Putnam.

"On Interference Bands in Mapping Spectra." By C. E. Kelley. (By invitation.)

"On the Distribution of Energy among the Particles of a Gas." By N. D. C. Hodges.

The following papers were presented by Henry B. Hill by title: —

1. "Dibromacrylic Acid."
2. "Dichloracrylic Acid."
3. "Relations of Dibromacrylic Acid to Two Different Tribrompropionic Acids."
4. "Certain Tetrasubstituted Propionic Acids.
5. "On the Constitution of the Substituted Acrylic Acids."

The following papers by Asa Gray were read by title: —

1. "Studies of Solidago and Aster."
2. "*Novitiæ Arizonicæ*, &c. Characters of New Plants, chiefly from Recent Collections in Arizona and Adjacent Districts."

Mr. Charles F. Mabery presented by title,

"Contributions from the Chemical Laboratory of Harvard College."

Seven hundred and fiftieth Meeting.

March 8, 1882. — STATED MEETING.

The PRESIDENT in the chair.

The Secretary of the Society of Arts having received a letter from General Hazen, Chief Signal Officer, U. S. A., in which the co-operation of that Society with the weather-service was invited, was instructed by the Society to ascertain, informally, whether the American Academy of Arts and Sciences, being the older and more strictly scientific body, would relieve the Society of Arts from the invited responsibility.

The following Committee was appointed by the chair to consider the proposition of the Society of Arts and to confer with the Society in regard to General Hazen's letter: —

WILLIAM WATSON, *Chairman.*
EDWARD C. PICKERING, WILLIAM H. NILES.

The following papers were presented: —

"On the Absorption of Light by Glass." By Edward C. Pickering.

"Ancient Peruvian Pottery, with Reference to the Characteristic Art of the People." By F. W. Putnam.

"Calibration of Thermometers." By Silas W. Holman, presented by Professor Charles R. Cross.

"The Crystalline Form of Tribromacrylic Acid." By W. H. Melville (by title).

Seven hundred and fifty-first Meeting.

April 12, 1882. — MONTHLY MEETING.

The PRESIDENT in the chair.

The Council recommended that the name of Frederick W. Putnam be transferred from Class II., Section 3, to Class III., Section 2. The Academy confirmed this recommendation.

The chair announced the death of Saint-Julien Ravenel, of Charleston, Associate Fellow of the Academy.

The following papers were presented: —

"On the Young Stages of some Osseous Fishes. Part III." By Alexander Agassiz.

"Wages as a Standard of Cost." By Edward Atkinson.

"On the Construction and Comparison of Three Standard Metres." By William A. Rogers.

"Note on Thermodynamics." By John Trowbridge.

"On a Modification of the Micrometer Level." By J. Rayner Edmands.

"On the Spirit-Level considered as an Instrument of Precision." By William A. Rogers.

"On the Colors and Patterns of Insects." By Hermann A. Hagen.

"On the Conditions of Electric Lighting." By N. D. C. Hodges.

Seven hundred and fifty-second Meeting.

May 10, 1882. — Monthly Meeting.

The President in the chair.

The President announced the death of Henry Wadsworth Longfellow, Ralph Waldo Emerson, and Charles Robert Darwin.

Dr. Gray referred to a communication from Mr. Winthrop, who represented the Academy at Darwin's funeral, and who mentioned that another Fellow of the Academy, Mr. Lowell, U. S. Minister, was also present.

The following papers were presented: —

"On Telegraphing over Great Distances." By N. D. C. Hodges.

"On the Limit of Visibility of Fine Lines Ruled on Glass." By William A. Rogers.

The following papers were presented by title: —

"On the Wedge Photometer." By Edward C. Pickering.

"On a New Type of Insects." By Samuel H. Scudder.

"Curcumin." Second paper. By C. Loring Jackson and A. E. Menke.

"Tumeric Oil." By C. Loring Jackson and A. E. Menke.

"On the Fatigue of Small Spruce Beams." By F. E. Kidder.

Mr. Sereno Watson presented by title the following contributions to North American Botany: —

1. "List of Plants from Southwestern Texas and Northern Mexico, collected chiefly by Dr. E. Palmer in 1879–80."

2. "Descriptions of New Species of Plants from our Western Territories."

REPORT OF THE COUNCIL.

MAY 30, 1882.

SINCE the last Report, May 24, 1881, the Academy has lost by death eighteen members, as follows: — eight Resident Fellows: John Bacon, Richard H. Dana, Ralph Waldo Emerson, Thomas P. James, Henry W. Longfellow, John A. Lowell, Theophilus Parsons, and Edward Reynolds; five Associate Fellows: Edward Desor, John W. Draper, Lewis H. Morgan, St. Julien Ravenel, and John Rodgers; and five Foreign Honorary Members: J. C. Bluntschli, Charles Darwin, Joseph Decaisne, Theodor Schwann, and Dean Stanley.

RESIDENT FELLOWS.

RICHARD HENRY DANA.

RICHARD H. DANA was born in Cambridge, Aug. 1, 1815. He and his brother Edmund attended school at Cambridgeport with Dr. O. W. Holmes and Margaret Fuller, who were, however, too old to be his associates. He entered Harvard College in the Freshman Class of 1831–2. In his Junior year he suffered from weakness of the eyes, and was forced to abandon his studies, making his famous sea voyage before the mast, and visiting what was then a strange country, California. Returning to college, he graduated in 1837 and entered the Law School, where he took the degree of LL.B. in 1839. The next year he assisted Professor Edward T. Channing by teaching elocution in the college.

Mr. Dana had inherited a taste for law, and also for literature. His grandfather, Francis Dana, who was born in Charlestown in 1743, at a critical period, was in responsible positions in the public service from

1774 to 1784. He was Judge in the Supreme Court of Massachusetts from 1785 to 1792, and Chief Justice from 1792 to 1806. As one of the founders of this Academy, a member of its Council from 1789 to 1805, and its Vice-President from 1805 to 1807, he is worthy of commemoration. His son, Richard H. Dana, Sr., was born in Cambridge in 1787, and graduated at Harvard College in 1808. In 1814 he entered the literary alliance which started the "North American Review," and in 1818–19 he was associated with Professor E. T. Channing in the editorship of it. Though he studied law, was admitted to the Boston Bar in 1811, and began practice in Cambridge the next year, serving also as member of the Legislature, he was for many years previous to his death, on July 2, 1879, only remembered as one of the early pioneers in American letters. In 1821–2 he published the "Idle Man." The "Buccaneer and other Poems," which was printed in 1827, was praised by Wilson in "Blackwood's Magazine" as being "the most powerful and original of American poetical compositions." When Richard H. Dana the younger graduated, the subject of his Part was: "Heaven lies about us in our infancy." This heaven, in his case, was the tastes and talents he had inherited.

What seemed at the time to be an unfortunate interruption in the college studies of the younger Dana turned out to his great advantage. It gave him a courage and robustness of character for which he found full exercise in later years. His "Two Years before the Mast," first published in 1840, which Dr. O. W. Holmes has characterized as the "Odyssey of the forecastle," has acquired a perennial popularity and made the literary reputation of its author. In the school at Amsterdam, where boys pass through a three years course of education for the merchant service, twelve copies are required in the library to supply the constant demand of the students for a book which competes successfully with Defoe's stories. Mr. Dana's interest in sailors, whose hardships, privations, and dangers he had shared, led him to publish another book in 1841 under the title of the "Seaman's Friend." This description of sea usages was republished in England under the name of the "Seaman's Manual." His next volume, "To Cuba and Back," which appeared in 1859, was the fruit of a short trip in which he was seeking rest from his professional labors. In 1859–60, Mr. Dana made the grand tour of the earth, stopping at the Hawaiian Islands, China, Japan, Ceylon, India, and Egypt, and revisiting California. His vivid description of this journey remains only in the memory of friends, except what relates to California. For that the public is indebted to the second edition, in 1869, of his first book, in which he records the pleasant recognition of old acquaintances in the Bay of San Francisco, and gives the reader all that is known of the history of his former shipmates, and of the ship itself, until it sank, a victim to the Confederate cruiser "Alabama."

In 1850 Mr. Dana edited "Lectures on Art, and Poems by Washington Allston." He wrote for the "Law Reporter," "the American Law Review," and the "North American Review." His eulogy on Edward Everett, pronounced at the request of the municipal authorities of Cambridge, on Feb. 22, 1865, and his oration at the centennial celebration, in 1875, of the revolutionary struggle in Lexington, rose to the height of the subject and the occasion, and fulfilled the promise of his youth as a writer and orator.

But these literary works, fascinating to young and old, and these orations, elegant in style and eloquent in delivery, were only episodes in the chosen life-work of their author. Mr. Dana was admitted to the Bar in 1840, and rose rapidly to eminence in his profession. He was familiar with maritime law, and acquired a large practice in questions of admiralty. He had opportunities, which he never lost, to befriend the common seaman, for whom he felt more than a sentimental sympathy. As a lawyer he trusted more to principles and less to precedents. Some of the cases in which he was engaged attracted an unusual share of public attention. In that of the Presbyterian Synod against the Parish of Dr. Channing, he discussed the title to public and religious charities. In Maine he defended the compulsory use of the Bible in the public schools. In 1845 he was engaged in a case of homicide which led to the revision of the criminal statutes in more than one State. He was interested in the Church, and employed to take part in disputes involving its relations to the State. In 1852 he acted in the Prescott controversy, and argued the bearing of the canon law of the Protestant Episcopal Church. After he had carefully prepared himself for his cases, he was ready and glad to meet the most eminent counsel that could be opposed to him.

In public life he realized the ideal scholar in politics. With no aptitude or taste for the practices of the politician, he had the qualities of a statesman. In the Free-Soil movement he was early associated with Charles F. Adams, Edmund Quincy, and John G. Palfrey, being a delegate to the Buffalo Convention of 1848. He was one of the counsel on the side of freedom in the fugitive-slave cases of Shadrack in 1853, and of Burns in 1854. As a member of the Constitutional Convention of Massachusetts in 1853, and as a speaker in the Republican campaigns of 1856 and 1860, he rendered valuable services to his State and to the country. From 1861 to 1866 Mr. Dana was the United States attorney for Massachusetts, resigning the office when it implicated him in the policy of Andrew Johnson, the acting President. In 1867–8 he gave a course of lectures in the Lowell Institute, and served in the Legislature of Massachusetts. His able discussion of the Usury law led to its repeal, and is reprinted and read now when most speeches are forgotten. In 1868 he entered the lists against General Butler as a candidate for Congress from the Essex district. Had he succeeded, his character, scholarship, and forensic eloquence would have raised him above the level of party to that of statesmanship. His failure is most to be regretted as leading to the coalition in the Senate in 1876 which resulted in his rejection when he was nominated by President Grant as Minister to the Court of St. James. The country could ill afford to lose a name which would have united with those of Everett, Motley, and Lowell in giving dignity to its representation in England.

The Civil War, and the settlement which followed it, raised questions of law with which Mr. Dana was well fitted to grapple. He drew up the Prize Act of 1864, and in connection with Mr. Evarts he argued prize cases before the United States Supreme Court, vindicating the rights of the Government in time of war in dealing not only with the belligerents, but also with loyal citizens. In 1867–8 he appeared before this court in the proceedings again Jefferson Davis. In 1866 he edited a new edition of "Wheaton's Elements of International Law," with additions and annotations of his own. Of his long controversy with a former editor of the book it is only necessary to say that it distracted the mind and wasted the time of Mr. Dana. His health had become the subject of anxiety to his friends, and in 1879 he went abroad, never to return, except for a brief visit after the death of his father. Mr. Dana had now come to be recognized as the highest American authority on international law. His notes on the history of the neutrality laws of the United States had been translated into French for the use of the arbitrators at Geneva, and were quoted by the counsel and in the final decision as authoritative. Mr. Wheaton had been dead many years, and his work was becoming scarce and antiquated. The time was opportune for preparing an independent treatise on the law of nations. Mr. Dana was well equipped for the task, and he might feel a laudable ambition to build upon the foundations partly laid by his grandfather. With this crowning work of his life projected, but hardly begun, but when his improving health gave promise of its final completion and of his return to this country, he died suddenly of pneumonia at Rome on Jan. 6, 1882, and was buried in the new Protestant cemetery outside the city's walls.

RALPH WALDO EMERSON.

In the death of Ralph Waldo Emerson the Academy has lost a member rarely seen perhaps at its meetings, and not owing his fame to any achievements in the fields in which its discussions are usually engaged, yet from his youth upwards accustomed to follow with a lively and sympathetic interest the triumphant progress of modern science, and always glad of an opportunity to see and to converse with scientific men. "I love facts," he said, "and hate lubricity and people of vague perceptions."

The earliest of his "lectures," read before the Mechanics' Institute in Boston, had for its subject "Water," and it was followed by one upon "The Relations of Man to the Globe." Afterwards he read an essay, entitled "The Naturalist," before the Boston Society of Natural History. His early note-books show many traces of his studies of natural science, and in the last conversation I had with him, a short time before his death, he recurred to what was always a favorite theme, the astonishing advance of scientific discovery during his life-time. In the series of lectures on the Natural History of the Intellect, first given, I believe, in England in 1848, and repeated, with modifications and additions, in the University Course at Harvard College in 1870, the central idea was that mind is matter come to self-consciousness, so that in the shapes and the laws of the physical world we may trace, as in cipher, the genesis of thought.

Ralph Waldo Emerson was the fourth child and third son of the Rev. William Emerson, minister of the First Church in Boston, and Ruth Haskins.' He was born in Boston, May 25, 1803, in the old parsonage in Summer Street, and was the descendant of several lines of faithful ministers, going back to the first settlement of the country; of Peter Bulkeley, one of the first settlers of Concord, Mass., and its first minister; of Daniel Bliss, prominent in Whitfield's "revival"; of the Moodys, famous preachers of Portsmouth and York, and one of them a predecessor of William Emerson in the First Church in Boston. His grandfather, the Rev. William Emerson, of Concord, of revolutionary memory, was the builder of the "Old Manse," and from its windows witnessed the fight at the bridge. Directly afterwards he joined the army as chaplain, and died in the service.

Ralph, as our Associate was called in his boyhood, did not distinguish himself in scholarship at school or college, but from very early years he was a diligent reader of English poetry, and showed much facility in versification. He entered Harvard College in 1817, and was graduated in 1821, receiving while there two Bowdoin prizes for dissertations and a Boylston prize for declamation, and he was chosen class poet. On leaving college he kept school, as his father and his grandfather had done before him, until he could find opportunity to follow the ancestral vocation of preaching. In 1826 he was "approbated to preach" by the Middlesex Association of Ministers, and in 1829 he was ordained at the Second Church in Boston as colleague of Rev. Henry Ware, Jr. Finding that the lecturer's desk would be more convenient for his purposes than the pulpit, he severed his formal connection with the church in the autumn of 1832, but continued all his life long a diligent seeker after and expounder of truth as applied to the conduct of life.

It would be out of place here to undertake to follow his fortunes in detail, or to attempt to determine his place as a moralist or as a man of letters. A full account of the occurrences of his life and a discriminating analysis of his philosophy may be found in the excellent work of the Rev. G. W. Cooke. (Boston: J. R. Osgood & Co., 1881.) Here it may be sufficient to recount some of the more prominent facts of his history.

In 1831-2 Mr. Emerson travelled in Europe, making acquaintance with many persons in England, particularly with Carlyle, whose first book, "Sartor Resartus," made its first appearance, in book form, in this country, with a preface by Emerson. In 1847-8 he again went to England, and there lectured extensively, being received with cordiality and with a lively interest by all classes of people. After his return home, his lecturing tours, which had been confined to New England and the cities of New York and Philadelphia, were extended to the West, and in 1871 he visited California.

In the summer of 1872 his house was partly burned, and although, by the prompt assistance of his friends and neighbors, his manuscripts and books were removed almost without injury, he received from this disturbance of his home a shock from which he never entirely recovered. His physical health, which, in spite of some delicacy of constitution, had been, since his early manhood, upon the whole remarkably good, continued unabated, but his command of words failed, and his mind lost its spring. Henceforth he wrote little or nothing, and although upon special invitation he would occasionally read one of his old lectures, he took but little part in the selection or preparation of it. His literary activity during this period was mostly confined to a revision of his poems for a new edition, and to a partial co-operation in the publication of a few essays written long before. The entire sanity of his intellect and the beautiful serenity of his disposition were untouched, but his memory, particularly of words, faded so as to render conversation a burden to him. At the funeral of Mr. Longfellow, a few weeks before his own death, it was remarked that he forgot the names of familiar acquaintances. A cold, taken a short time afterwards, passed into pneumonia, of which he died April 27, 1882, a few weeks short of his 79th birthday.

Mr. Emerson delivered the annual oration before the Φ. B. K. Society in 1837 and in 1867. He received the degree of LL.D. from Harvard College in 1867, and was chosen Overseer in the same year. In 1878 he was chosen Foreign Associate in the Academy of Moral and Political Sciences of the Institute of France, to fill the place left vacant by the death of Mr. J. L. Motley.

The following is a list of his principal published works: — Nature, 1836; Φ. B. K. Oration, 1837; Essays, first series, 1841; Address on the Anniversary of Emancipation in the West Indies, 1844; Essays, second series, 1844; Poems, 1847; Miscellanies, 1849; Representative Men, 1850; Memoir of Margaret Fuller, 1852; English Traits, 1856; Conduct of Life, 1860; May-day and other Poems, 1867; Society and Solitude, 1870; Letters and Social Aims, 1875; Fortune of the Republic, 1878.

THOMAS POTTS JAMES.

Thomas Potts James died, at his residence in Cambridge, Feb. 22, 1882, in the seventy-ninth year of his age. He had been a Fellow of the Academy for only four years, most of his life having been spent in Philadelphia, in the neighborhood of which city he was born on the 1st of September, 1803. His paternal and maternal ancestors were notable persons among the earlier settlers of Pennsylvania. For forty years he was engaged in business in Philadelphia as a wholesale druggist, on the relinquishment of which he removed to Cambridge, bringing his wife and their four children to her paternal home. From his youth he was more or less devoted to botany; but of late years, having more leisure for the indulgence of his taste, and wishing to be more than an amateur, he devoted himself exclusively and most sedulously to bryology, in which he became a proficient. After the death of Mr. Sullivant in 1873, Mr. James and our Associate, Lesquereux, were looked to as the principal authorities upon Mosses in this country; and the duty appropriately devolved upon them of preparing the systematic work upon North American Bryology which Mr. Sullivant had planned. Owing to the pre-occupation of Mr. Lesquereux in vegetable palæontology, the laboring oar fell to Mr. James. He had already published some papers upon the subject in the Transactions of the American Philosophical Society, of which he had long been an active member, and he had contributed to Mr. Watson's Botany of Clarence King's Exploration on the Fortieth Parallel a notable article on the Musci of that Survey. Our own Academy has also published some of the results of the joint study of these two veteran bryologists. The characters of Mosses in these days are mostly drawn from their minute structure. Hundreds of species and varieties in numerous specimens had to be patiently scrutinized under the compound microscope, the details sketched, and collated, and the differences weighed. To this task Mr. James gave himself with single and untiring devotion. He had nearly brought this protracted labor of microscopical analysis to a conclusion, and was actually engaged in this work, when the eye suddenly was dimmed and the pencil dropped from his hand. Partial paralysis was soon followed by coma, and he died within a few hours. So very much has been done, that it is confidently hoped that his coadjutor may soon bring the work to a completion, and give to bryological students the Manual of North American Mosses which is greatly needed, and to which a vast amount of faithful research has been devoted. The name of Mr. James will thereby be inseparably associated with the advancement of an interesting branch of botany. He was not often seen at our meetings, but he is greatly missed by his associates in study, and his memory is cherished by all who in the various relations of life came to know this diligent and conscientious student of nature, and most estimable, simple-hearted, kindly, and devout man.

HENRY WADSWORTH LONGFELLOW.

Henry Wadsworth Longfellow was born in Portland, Maine, on the 27th of February, 1807. He died in Cambridge, Mass., on the 24th of March, 1882. At the age of fourteen he entered Bowdoin College (founded by the first President of the Academy), in a class which his own name and that of Nathaniel Hawthorne have made illustrious. In 1826, one year after receiving his degree, he was appointed Professor of Modern Languages at Bowdoin. In 1834 he was chosen to succeed the eminent scholar, Mr. George Ticknor, as Professor of Modern Languages in Harvard University. He resigned in 1854, and James Russell Lowell, now Minister to England, was elected to the vacant chair. In the mean time Mr. Longfellow had made three long visits to Europe, accomplishing himself for his professorial duties, and gathering rich materials for his pen. For forty-six years he resided in Cambridge, most of the time in the historical mansion known as Washington's headquarters.

In the removal of the name of Mr. Longfellow from the list of its Fellows, the Academy bears its share in a great national loss. There is no need to give a more extended account of a life so illustrious as that of Mr. Longfellow, or to enumerate his familiar and secure titles to fame.

For the space of a whole generation he has been the most popular and beloved of American poets. No poet who has ever written in the English language has addressed a wider audience among his contemporaries in other countries as well as in his own, and none has ever attached his readers to himself with firmer ties of personal regard. The distinguishing characteristic of his poetry was its simple, sincere, and exquisite expression of sentiment and emotion common to the hearts of men, and of the sympathy of the poet, at once strong and delicate, with the deepest and the most familiar experiences of human life. His poetry evoked the sympathy of his readers, and it strengthened their best feelings by giving natural, appropriate, and beautiful utterance to them. The service is incalculable which Mr. Longfellow has thus rendered in refining, purifying, and elevating the moral disposition of his numberless readers. His broad and liberal culture, his native sense of poetic melody, his fine and critical taste, his admirable skill and culture as an artist in verse, all contributed to the worth and to the success of his work. But its chief source of power lay in the character of the man. His poems in their excellence were the true image of the poet. It was the man speaking in them that gave to them their force of good. Sincerity was in the very tone of their music.

The range of the subjects of his poetry was astonishingly wide. The legends of the Old World and of the New, of the North and of the South, deeds of patriotism and of devotion, stories of the past and of the present, themes of household and domestic concern, of birth and death, of joy and sorrow, were equally familiar to his lyre of many strings.

In his volumes there was something for every age and every taste. But in this variety, diverse as it was in motive and in interest, there was an essential and controlling unity of spirit. It was all inspired with the sweet and generous nature of the poet, his faith in man, his trust in God, his high purpose and principle, his allegiance to duty.

Modest, simple, kind, tender-hearted, beloved by all who knew him, famous throughout the world, he has left a memory in which there is nothing to regret, and which will forever be cherished by his country.

JOHN AMORY LOWELL.

John Amory Lowell died, at his residence in Boston, on the 31st of October last, when he had almost completed the eighty-third year of his age, for he was born on the 11th of November, 1798. A few years of his boyhood — from 1803 to 1806 — were passed in Paris, where he was a spectator of some of the glorifications of the First Empire, especially on the occasion of the return from Austerlitz. He entered Harvard College in 1811, Messrs. Sparks, Parsons, and Palfrey being among his classmates, and after graduation he entered a mercantile house. He was elected into this Academy on the 10th of November, 1841, at the same time with two other Fellows assigned to the botanical section. One was William Oakes, of Ipswich, who died seven years afterward; to the other is assigned the duty of preparing this memorial. When the Fellows of the Academy were arranged in classes and sections, the pronounced tastes inherited from his father, and cultivated by his own studies, made it natural that he should belong to the small section of botany. But he might with equal propriety have been relegated to more than one section of the third class. For, notwithstanding his devotion to business affairs, his classical and linguistic knowledge were always well kept up, and his authority upon economical and financial questions was great.

The family has always had a marked representation in this Academy. To mention only the direct line, the subject of our notice was chosen into it very shortly after the death of his father, — the John Lowell who, after achieving distinction and a competency at the bar, retired from active practice at the age of thirty-four, to be known through his valuable writings as "The Norfolk Farmer," and as a principal promoter, if not the founder, of scientific agriculture and horticulture in New England. John Lowell — the father of John Amory Lowell — was elected into the Academy in the year 1804, soon after the decease of his father, the Hon. John Lowell, first judge of the United States District Court of Massachusetts, under a commission from Washington. This office is now held by his great grandson, the eldest son of our deceased Associate, who has been a Fellow since the year 1877, thus continuing the line from the very foundation of the Academy, for Judge Lowell was one of the sixty-two members incorporated by the charter in 1780. In tracing the genealogy one step farther back, we come (as is almost universal in New England families of note), upon a clergyman, the Rev. John Lowell, of Newbury, a man of mark in his day.

Mr. Lowell was the fourth of his family to be a member of the Corporation of Harvard University, to which he gave a continuous and most valuable service of forty years. He was for more than fifty years one of the directors of the Suffolk Bank, which was chartered in his time, and which early established a very useful plan for the redemption of the currency of the New England banks in Boston. Not to mention other important public trusts, — as of the Athenæum, of the Massachusetts General Hospital, of the Agricultural Trustees, of the Provident Institution for Savings, to all of which he rendered assiduous and wise service, — nor to refer here to the very important part which he has taken for a lifetime in the development of the manufacturing interests of Massachusetts, especially as prosecuted in the town which was named in commemoration of similar services by his cousin, — we proceed to speak of that most important "corporation sole" founded by that cousin, the Lowell Institute. This trust was specifically consigned to our late Associate and to such successor as he should appoint, — with preference to the family and the name of Lowell, — subject to no other than a formal visitatorial control, mainly for auditorship. And "to him, single and alone, it fell to shape the whole policy and take the whole direction of this great educational foundation," the history of which for almost half a century has justly been said to be a "record of his own intellectual breadth and scope, as well as of his large administrative capacity." We all know with what good judgment, with what liberality, and with what success this peculiar trust has been administered, and how on the one hand a series of most distinguished men have been attracted into its service, while on the other the efforts of younger men have been stimulated and rewarded at the period when such encouragement was most important to them. Suffice it to mention the names of Lyell and Agassiz, — the former early and also a second time brought from England for courses of lectures at the Lowell Institute, the latter a permanent acquisition to us and to our country. Through Mr. Lowell's discernment, moreover, the first encouragement to devote his life to scientific pursuits was afforded to Jeffries Wyman, by the offer of the curatorship of the Institute as well as of a lectureship. The intellectual and the financial interests of this trust have equally prospered in Mr. Lowell's hands; for while the number of lecture-courses has been doubled, and various subsidiary lines of instruction have been developed, the principal of the fund has been increased to thrice its original amount.

Mr. Lowell's fondness for botany developed shortly after he left college, and was incited by the botanical intercourse between his father and the late Dr. Francis Boott, with whom he maintained a lifelong friendship. But it was only in about the year 1844 or 1845 that he began the formation of an herbarium and botanical library; and this was actively prosecuted for several years, in evident expectation of comparative leisure which he could devote to scientific studies. He subscribed liberally to the botanical explorations in our newly-acquired or newly-opened Western Territories; and when in Europe, in 1850 and 1851, he added largely to his store of rare and costly botanical books. But just when he was ready to use the choice materials and appliances which had been brought together, the financial crisis of 1857 remanded him to business. The grave duties and responsibilities which he resumed he carried up nearly to the age of fourscore, — carried as it were with the vigor of early manhood and the cheerful ease that attends "a real love of work for the work's own sake." And when it became evident that the comparatively unbroken attention requisite for serious botanical study was not to be secured, and as soon as a building was prepared for their reception, he presented all his botanical books which were needed to the herbarium of Harvard University; and the remainder, with his herbarium, to the Boston Society of Natural History, — not giving up the while his studious habits, but transferring his attention back to the Latin and the French classics, and in a certain degree to German and Italian literature.

As his father was one of the leading promoters of the establishment of the Botanic Garden of Harvard University, Mr. Lowell was also its most efficient supporter through its years of sorest need; and, in memory of his father, he bequeathed to it the sum of $20,000 in order to make his annual subvention perpetual. He made a legacy of equal amount to the general Library of the University, which he along with his father and grandfather had served in a most responsible trust for seventy years. He never sought or accepted any office in city or State; but few men were more sought for responsible trusts, or ever served their day and generation more devotedly, disinterestedly, and wisely. He seemed always to have a firm confidence in his own judgment, and that confidence appears not to have been misplaced.

THEOPHILUS PARSONS.

Theophilus Parsons was born in Newburyport on May 17, 1797, and died in Cambridge on Jan. 26, 1882. His father was the celebrated Chief Justice of the same name. His mother, whose maiden name was Elizabeth Greenleaf, was the daughter of Judge Benjamin Greenleaf, of Newburyport, and the granddaughter of Dr. Charles Chauncy, of Boston, and through the latter she was lineally descended from Dr. Charles Chauncy, the second President of Harvard College. When he was three years old his father removed from Newburyport to Boston, where he continued to reside for thirteen years and until his death. The son's boyhood, therefore, was spent in Boston, and his earliest recollections must have been of that place. During his boyhood his father procured a Mr. Elisha Clap to come to Boston and open a private school, and at this school the son was fitted for College. At the age of fourteen — namely, in 1811 — he entered Harvard College. His father was then Fellow of the College, and Dr. Kirkland, his father's former pastor and most intimate and valued friend, was President. With the latter the son went to live upon entering College, and he continued to live with him during his entire College course. His class at the time of its graduation numbered sixty-six, and among his classmates were George Eustis, late Chief Justice of Louisiana, Convers Francis, Thaddeus W. Harris, John Jeffries, John A. Lowell, John G. Palfrey, and Jared Sparks. All of these distinguished men he survived, the last of them, John G. Palfrey, having died on April 26, 1881, and he was himself survived by only two of his sixty-five class-mates.

Immediately upon graduating, he entered the office of William Prescott, the son of the hero of Bunker Hill and the father of the historian, and then the acknowledged leader of the Suffolk Bar, and began the study of law. In 1818 he was admitted to the Bar; in 1822 he removed to Taunton, and there engaged in the practice of his profession; in 1828 he returned to Boston, and there continued the practice of his profession for the next twenty years. In the summer of 1848, on the resignation of Professor Greenleaf, he was appointed Dane Professor of Law in Harvard University, and at the beginning of the academic year 1848–49 he assumed the duties of his professorship, delivering the opening lecture in the Law School on Monday, Aug. 28, 1848. About the same time he removed to Cambridge, where he continued to reside until his death. He held his professorship and discharged its duties for more than twenty-one years; namely, until the middle of the academic year 1869–70, when he resigned and retired from active pursuits.

Professor Parsons, like his father, had great versatility of talent, and like him was distinguished for his attainments in various branches of learning; but, unlike him, he was a very prolific writer, not only upon legal subjects, but upon literary and religious subjects as well. Any notice of him, therefore, which fails to present the many-sidedness of his intellectual character must necessarily be incomplete; and yet the present notice must be confined to his professional character, as the writer is not competent to speak of him in any other.

He had the great misfortune to lose his father just as he had nearly reached that period of life when the latter would have been of priceless service to him in the profession which he chose.* As it was, it is doubtful if he derived from his father any professional advantage whatever. Whether his choice of a profession was due in any degree to his father's wishes or influence is not known. However that may be, there is some reason for doubting whether the choice was a wise one. It is clear that he never thoroughly enjoyed the practice of law, and his talents, great and brilliant as they were, were not precisely of the kind to qualify him to excel in law as a science; and it is doubtful whether, under ordinary circumstances, he would have achieved such a degree of success in the profession as would have satisfied either himself or his friends. In a word, he had not what is called a legal mind. So far as law depends merely upon principles of right reason and abstract justice, he was fitted to excel in it, and he liked it; but in so far as it depends upon what is called technical reasoning, he regarded it with aversion, and he seemed to have the same inaptitude for that kind of reasoning that many persons of otherwise fine talents have for mathematics, for example. Accordingly, he always disliked the law of real property, and openly avowed his incapacity for it; and the same was true in a great measure of the com-

* Chief-Justice Parsons died Oct. 30, 1813, when Professor Parsons was sixteen years old and in his Junior year in College.

mon-law system of procedure. Indeed, the early common law of England in general he regarded with little favor. On the other hand, commercial law was his delight, but more especially commercial law as resting upon the custom and practice of merchants, and as it exists all over the commercial world; for commercial law as administered in the common-law courts of England and America had in it too much of the leaven of common law to be altogether satisfactory to him. It was for this reason, and because of the simplicity and celerity of its procedure, that the Court of Admiralty was so great a favorite with him. Nothing is known to the writer of his practice in Taunton; but it is impossible that he should have done much there, for it was not a field in the least suited to his genius. Upon coming to Boston, however, he must soon have made his mark as a commercial lawyer, and particularly in the law of marine insurance; for in 1838 he appears in three reported cases as counsel for as many different marine insurance companies; and one of these cases was the important one of Peters *v.* The Warren Insurance Company (14 Pet. 99), which he argued first against Mr. F. C. Loring, before Judge Story, and afterwards against Webster before the Supreme Court at Washington. It was after he retired from practice, however, that he acquired his greatest professional reputation, partly as a professor in the Law School and partly as an author. Before going to Cambridge, his reputation was at best but local, while after that event his name became familiar to every lawyer in the United States. Undoubtedly his books had the greatest agency in producing that result. The first book which made him widely known was that upon Contracts, one volume of which was published a little more than five years after he had assumed the duties of his professorship. This was one of the most successful law books ever published in this country. The subject is as fundamental, as extensive, and as important as any in the law, and this work immediately took its position as the standard American authority upon that topic, — a position which it has maintained without question from that day to this. It has passed through six editions; but this statement conveys no adequate idea of the extent of its sale, for it has long been stereotyped, and the writer has been informed that there were ten thousand copies of the fifth edition sold.

There is no occasion to speak of Professor Parsons separately as a professor of law and as a writer of law books. In both capacities he was a teacher, and in both he achieved his success by the same means: namely, by his gifts as a teacher. In a teacher of law, whether his teaching be oral or by published writings, one of the indispensable requisites for success is the power of making himself thoroughly and easily understood by one who is unacquainted with the subject taught. With this power one can scarcely fail of a fair degree of success; without it the greatest talents and attainments may come to naught. It may be said, indeed, that this power is equally indispensable in a teacher of any other subject, and literally, of course, this is true; but in most subjects the difficulty of making one's self understood is believed to be less great than in law, and hence the power of doing so less rare. This power Professor Parsons possessed in a very eminent degree. He had, indeed, a positive genius for simple and lucid statements. Whatever he clearly understood himself he seldom failed to make perfectly intelligible to his hearers or readers, even if they were laymen; hence his lectures and his books were always popular. Nor need it be wondered at that one whose genius did not specially fit him for the law should have made so great a figure in it; for those who have a special genius for law are seldom successful in teaching it, except to those who have already obtained a considerable mastery of it. Sir Edward Coke, for example, is the greatest name in the English law, and yet his writings are to the tyro not merely unintelligible, but repulsive. On the other hand, Sir William Blackstone never made a great figure in the practice of his profession, and, though he was made a judge, he never distinguished himself in that capacity; and yet his Commentaries have been more read and more admired than any other law book in the English language. The secret of Blackstone's great success was that he excelled all other legal writers in his style and in his mode of treating his subject; and the merits of Professor Parsons were not unlike those of Blackstone. It may be added that Professor Parsons was a great admirer of Blackstone, and probably there is no legal author with whom he would have been so proud to be compared.

EDWARD REYNOLDS, M.D.

Edward Reynolds was born the 28th of February, 1793, in Hawkins Street, Boston. His father was Edward Reynolds, a merchant of Boston, whose wife, his mother, was Deborah, daughter of Samuel and Deborah Belcher. There were five other children, two sons and three daughters.

The subject of this notice was trained for college principally at the Boston Latin School, under Masters Hunt and William Biglow.

Among his schoolmates were Harrison Gray Otis, Nathaniel L. Frothingham, and Edward Everett.

He entered Harvard College in 1807, at the age of fourteen, and graduated in 1811. After graduating, he tried his father's counting-room for a few months, but finding himself not inclined to business pursuits, gave them up and began the study of medicine with Dr. John Collins Warren. From 1815 to 1818 he continued his medical studies in London and in Paris. He worked very hard, as is shown by the eight or ten manuscript volumes of lectures copied out carefully, and all carefully indexed. He was conspicuous by his stature of six feet four inches, and the story is told that when a Briton was expatiating on the degeneracy and diminished size of the Anglo-Saxon in America, he and his companion, General McNeil, also a man of very large development, rose and introduced themselves as examples of the degeneracy spoken of.

Having finished his studies in Europe and having been admitted as Fellow of the Royal College of Surgeons, he returned to Boston in 1818, and established himself there as a practitioner. His favorite branch was surgery, but his attention was called to one of its specialties by a particular circumstance. He found, on his return, that his father, now sixty years old, was the subject of cataract in both eyes, upon which he performed his first operation, confidently and successfully. This happy event naturally turned his attention to diseases of the eye, and led others who were the subjects of them to apply to him. Thus, though he never chose to be called an oculist, he was largely consulted in that class of affections. Being impressed with their frequency, and the difficulty of treating them properly among the poor, he in conjunction with the late Dr. John Jeffries, set on foot, and finally succeeded in permanently establishing, the Massachusetts Eye and Ear Infirmary, now one of our most valued public institutions. To this infirmary he devoted many years of faithful service, and when, in the course of time, it passed into the care of younger hands, he still retained all his interest in its welfare, and watched with honest pride its growth and prosperity.

In the year 1837, during the absence of Dr. Warren, the Professor of Anatomy and Surgery in Harvard University, Dr. Reynolds delivered the course on Anatomy, having had a very limited time for preparation, but performing the task in a most acceptable manner. At about the same time he joined Dr. David Humphreys Storer in a plan for giving a more complete course of private instruction than had hitherto been known in Boston. They associated with themselves Dr.

Jacob Bigelow and Dr. O. W. Holmes, and afterwards Dr. J. B. S. Jackson and Dr. Henry J. Bigelow. This school had a long and successful career, until its place was taken by the summer medical school of Harvard University.

No one could look on Dr. Reynolds without being struck by his majestic physical aspect. By many he was thought to resemble Washington as we see him in portraits, but Washington with almost colossal proportions. So remarkable an outward presentment would not unnaturally lead many to overlook other gifts, which were exceptional, and worthy of being noted. He had a natural artistic talent, which showed itself in the sketches he made in his note-books,—a talent his fellow-students and friends might never have suspected if some accident had not betrayed it, as he made no parade of any of his accomplishments. He had a strong literary taste also, and entered upon the study of the German language by making a careful translation of Faust into blank verse as his first effort.

He was a man of a most cheerful and delightful disposition, full of pleasantry, but thoughtful as well as hopeful, a friend whom it was a happiness to meet, and from whom, on parting, one brought away the remembrance of cheering tones and smiles that made life look brighter. His conversation was lively and entertaining; he was fond of anecdotes and told them well, and his honest, hearty laugh carried with it better credentials of goodness than many a man's confession of faith.

As I last remember him, he was on the verge of ninety years. His ponderous frame was a great burden for such extreme old age, and his movements were somewhat difficult and feeble. His imperfect hearing rendered conversation with him somewhat difficult, but his talk was vivacious and interesting to a remarkable degree.

In his early years Dr. Reynolds listened to the preaching of Mr. Buckminster and of Dr. Channing. He joined the Episcopal Church later in life, and remained in communion with that Church until the time of his death, which occurred on the morning of Christmas Day, 1881.

ASSOCIATE FELLOWS.

HENRY CHARLES CAREY.

Henry Charles Carey,* born in Philadelphia, Dec. 15, 1793, was elected an Associate Fellow of this Academy Nov. 11, 1863. By his death, which occurred Oct. 13, 1879, in his native city, economic science has lost the most eminent of its American investigators.

Mr. Carey was the son of Matthew Carey, an Irish exile who in the earlier part of this century had become a man of mark in this country both as a publisher and as a writer on economical and political questions. The son took an important place in his father's establishment when only twelve years old, and upon his father's retirement in 1821 became the leading partner in the well-remembered publishing house of Carey and Lea; and finally, after a prosperous career, retired from active business in 1835, and from that time devoted his leisure to economic science and to an extensive range of collateral investigations. Beginning with the publication of an essay on the Rate of Wages in 1835, his fertility as an author continued until his death. Thirteen octavo volumes and three thousand pages in pamphlet form are the visible memorials of his activity, while it is estimated that twice this amount of matter was contributed by him to the newspaper press. When it is added that some of his more important works have been translated into French, Italian, Portuguese, German, Swedish, Russian, Magyar, and even Japanese, it is clear that few writers on economic topics have had his power of commanding the attention of readers and his opportunity for directing the course of scientific thought.

This remarkable success as an author, in a field not usually attractive to a wide circle of readers, was no doubt due in part to the inherited fervor with which he entered into economic discussion, but also in part to the boldness of his undertaking, which was nothing less than a revolution in the methods and in the doctrines of political economy. He began his work at a time when the English school appeared to have exhausted its deductions from assumed premises, and to be reluctant in applying its conclusions under the varied conditions of society as it is. The agitation of social questions was gather-

* Notice omitted in Vol. XV.

ing strength through the whole of his literary life, while the rapid industrial expansion which marks the century gave a new and powerful stimulus to inquiry as to the forces which govern the development and well-being of nations. Our countryman announced a series of discoveries in social science, and in political economy the leading division of that science; the announcement was so made as to command universal attention, and the value of the declared discoveries became a question of debate among students of economic theory. In Germany especially, the question whether Mr. Carey has made a scientific revolution has been discussed in several published essays by Dühring, Held, Lange, and Wirth. The same question has attracted attention both in France and in Italy, and it is perhaps only in England that it has been treated with indifference.

Mr. Carey himself has stated the order in which his discoveries were made, in the introduction to his Principles of Social Science, his most important work. The point of departure was a new theory of value, which he defined as the measure of the resistance to be overcome in obtaining things required for use, or the measure of the power of nature over man. In simpler terms, value is measured by the cost of reproduction. The value of every article thus declines as the arts advance, while the general command of commodities constantly increases. This causes a constant fall in the value of accumulated capital as compared with the results of present labor, from which is inferred a tendency towards harmony rather than divergence of interests between capitalist and laborer. This theory, which at first seems easily reconciled with the real import of the ordinary theory of cost of production, Mr. Carey applied to every case in which value could be predicated, — to commodities, services, and land alike. Indeed, in passages which seem not wholly metaphorical, it is applied to man himself. In the case of land and its products, the theory led naturally to the position that their value is due solely to the cost of reproducing the like, monopoly of possession having no agency, and every gift of nature being in itself gratuitous and without value. This theory appears in Mr. Carey's "Principles of Political Economy," published in 1837–40, and is found in slightly different terms in Bastiat's "Harmonies Économiques," printed in 1850, where it was made to do effective and welcome service as a defence of property, and especially of property in land, against the attacks of the socialists of Proudhon's school. The question as to Bastiat's unacknowledged indebtedness to Mr. Carey was discussed, but hardly settled, in a series of letters in the "Journal des Économistes" for 1851. Of these letters that most unfavorable to Bastiat's literary integrity is his own unsatisfactory letter of explanation.

The chief importance of this theory of value, whether in its original form or as revised by Bastiat, will be found to consist, we believe, in its alleged universality. It would hardly have been thought an epoch-making contribution, had it not offered a basis on which to rest the value of land and labor as well as of goods. But this claim to universal applicability, it may be safely predicted, will never be made good. The differing values of land, according to situation and quality, and the changes of value resulting from the good or bad effects of improved communication or newly-discovered resources, present a range of insoluble contradictions, on which forty years of effort have made no impression. As a theory of partial application, Mr. Carey's statement offers acknowledged attractions, but it lends itself with difficulty to any precise and thorough analysis of the phenomena of exchange, — a branch of inquiry in which both he and Bastiat are singularly deficient.

Ten years later, Mr. Carey tells us, he discovered a law of production from land the exact reverse of Ricardo's, and presented it in his "Past, Present, and Future," published in 1848. The new theory, which is well adjusted to that of value already announced, declares that in the progress of society men begin with the cultivation of light and easily-worked soils, and as they accumulate capital and increase in numbers take up the richer but less manageable lands, so that with the advance of the community there is a progressive gain in the rate of return from the land and an increasing cost of subsistence. Although this statement of the historical course of settlement of new countries was announced and subsequently relied upon as a formal refutation of Ricardo's system, a follower of Ricardo might accept it without difficulty, and yet find the essentials of the Ricardian doctrine untouched. The real question does not relate to the order of occupation of the soil, but to the causes which at a given time make one piece of land more valuable than another, and the relation of these causes to distribution in a given state of the arts of production. But although Mr. Carey's historical discovery — the validity of which he supported by facts collected in a remarkably wide range of reading — had not the logical results which he claimed for it, it brings to view one of the most interesting questions connected with the evolution of human society. It is to be said, moreover, that the order of development which he denies had been treated as the true historical order by many economists, and that in this as in numbers of other cases his vigorous attack compelled the revision of some too hasty generalizations.

Closely connected with this proposed substitute for Ricardo's doctrine was Mr. Carey's rejection of the Malthusian law of population. His attack upon that celebrated dogma was renewed at every opportunity and with every rhetorical weapon at command. And as the doctrines of Ricardo and Malthus are in a sense complementary, so Mr. Carey's own law of distribution and his theory of production from land seemed to carry with them as a natural deduction an anti-Malthusian conclusion of continually-increasing ability to support increasing numbers. Logical necessity, however, forced him to seek for some ultimate limiting principle, and this he at last found in Herbert Spencer's conjectured physiological law of the diminution of human fertility.

But, after all, Mr. Carey declares, "the great and really fundamental law of the science . . . still remained to be discovered." For a statement of this crowning discovery he refers to the second chapter of his "Social Science," in which is ingeniously developed "the great law of molecular gravitation as the *indispensable* condition of the existence of the being known as man." This law may be better comprehended from the summary statement made elsewhere, that "the laws of being [are] the same in matter, man, and communities;" that "in the solar world attraction and motion [are] in the ratio of the mass and the proximity;" and that "in the social world association, individuality, responsibility, development, and progress [are] directly proportionate to each other." That there is, not analogy, but absolute identity of law in the physical and in the social world, is indeed laid down in a multitude of passages of the "Social Science," and is maintained with great vigor in Mr. Carey's latest volume, "The Unity of Law," published when the author was in his seventy-ninth year. It is clear that the author might well regard the discovery of a law that should be common to the material world and to human society as opening to view fundamental relations never before reached. Few would now be found to maintain, however, that any such discovery was really made, or that Mr. Carey did more than select from physical science certain striking analogies, often tending to illustrate social phenomena, but not proving any law common to subjects so diverse as mind and matter.

Finally, it must be remarked that while Mr. Carey's conception of social science, like Mill's, is that of a broad field, only a part of which is occupied by political economy, he failed even in his "Principles of Social Science" to do much more than discuss economic forces, and especially failed to apply his conclusions constructively in settlement of any of the great questions of government. The sympathetic writer of his memoir, Dr. William Elder, declares that Mr. Carey in his chief work consciously failed to devise a system of political government by the application of his established principles. "His last chapter, the fiftieth of that work, is a virtual and, as I happen to know, a conscious surrender of the attempt."

Of what have been supposed to be Mr. Carey's greatest direct contributions to science, then, it is not probable that much will be found to hold a permanent place. This result of a life devoted to investigation is no doubt due in part to an ardor of temperament which caused him to tolerate with difficulty the impartial processes of science, and even made it hard for him to comprehend the logical methods of opponents and the real position of questions in dispute. It is also due in part to his burning interest in the practical questions of his time. He saw these questions on their economic side, not merely as phenomena illustrating the studies of his closet, but as touching the very life of his nation, and he bent all his powers to the discussion of them for the practical purpose of effecting their settlement. Of the enormous mass of his pamphlets and of his minor contributions to the press a large part is strictly controversial, and the habit of mind thus formed is felt everywhere in his larger works of the last thirty years. Of the questions of the day none concerned him so deeply as that of a protective tariff. Originally a believer in free trade, in sympathy with a local current of thought now almost forgotten, and a firm believer in the natural harmony resulting from economic laws, he arrived at the opinion that to secure this harmony from disturbance and to arrive at final freedom of trade, the co-ordinating power of government must be used in the form of high custom duties for the protection of domestic manufactures. From this time (not far from 1845) he was a zealous and even passionate advocate of protection. No observed fact, no meditated theory was for him without its bearing on this controversy; and upon reading his chief work it is impossible to doubt that this absorbing interest in one question destroyed his scientific equilibrium, or indeed to see how it could well be otherwise.

But the disappearance of Mr. Carey's supposed contributions to scientific theory will leave science still largely indebted to him for such services as few men are qualified to render. Political economy has no doubt shown a dangerous tendency to settle into intellectual routine and stagnation. It was Mr. Carey's distinction that, by the freedom of his own speculations and the power with which they were supported, he compelled a revision of much of the ground, that he stimulated fresh inquiry and opened up new lines of thought. His school is nowhere numerous: it may be doubted whether it is destined for long life; but it is everywhere earnest and independent, provocative of discussion, and thus finally serviceable to the truth. It has been well said by one of his warmest supporters that his system is an intellectual ferment of the strongest kind. It is no small service to have communicated this leavening influence to political economy at the time when the orthodox school of economists appeared to have finished their work.

It is also to be said that Mr. Carey rendered an important service by the direction which he sought to give to the discussion of the protective system. In this great debate it has been the failing of the friends of free trade to keep their attention fixed, often exclusively, on the gain which freedom offers to the consumer. The questions of added stimulus to producers, of more rapid societary movement, of earlier diversification of pursuits, and of quickened thought, all resulting in fresh gain in productive power, have been little considered by them. The gains thus promised by protection have seemed to its opponents to be indirect and contingent, and to lie outside of the economic range. But it was upon such gains as these that Mr. Carey's mind was constantly bent. The home market was to him of chief importance, because with its growth he believed would grow the power of association, the rapidity of exchange, the intellectual capacity of individuals, and the power and harmony of the whole society. In dealing with these considerations political economy rises into a higher region of thought than that with which it is apt to content itself. Whatever Mr. Carey's error in supposing that the logical result of these lofty speculations must be the vindication of the policy of protection, the world is permanently the gainer by his stimulating attempt to show where the highest truths are to be sought.

EDWARD DESOR.

Edward Desor was born in Friedrichsdorf, near Homburg, in 1811. He died on Feb. 23, 1882, at Nice, where he spent the winter. His father was a manufacturer. The son, French by descent, though born in Germany, united the science and literature of both nations, and spoke both languages with facility. After studying law at Heidelberg and Giessen, he fled to France in 1832 on account of political movements, and devoted himself to natural history with Eifer in Paris. His first work was the translation of Ritter's Geography. Élie de

Beaumont inspired him with a love for geology and the physics of the globe. At the gathering of the Swiss naturalists in Neuchâtel in 1837, he met Agassiz and Carl Vogt, and their influence determined his future scientific life. He remained at Neuchâtel to study with them the geology and meteorology of Switzerland, and to take part in their celebrated explorations on the Aar Glacier. In 1841 he published an account of their united observations, made during six summers in the world of glaciers.

Having visited the glaciers of Scandinavia, Desor accompanied Agassiz to the United States in 1847, where he soon found a field for his scientific activity in connection with the U. S. Coast Survey. In 1847 Congress had authorized a geological survey of the Lake Superior district, under the direction of C. T. Jackson. When Dr. Jackson resigned, at the end of two summers, the survey was put in charge of J. W. Foster and J. D. Whitney, and Desor was one of the first assistants. Alluvial deposits and their fauna were assigned to him. His researches on the drift in Western Europe, on the glaciers of Switzerland, and on the formation of shoals along the Atlantic coast of the United States, qualified him for this work, and ensured his success. Besides the part which he contributed to the Report of the Survey, he published his views on the drift of Lake Superior in the "American Journal of Science" (xiii. 93, 1852). Desor first introduced the word "Laurentian" to describe geological formations in Maine, on the River St. Lawrence, and on Lakes Champlain and Ontario; but the word was appropriated afterwards by the Canadian geologists for another purpose. The earlier and the later publications of Desor appeared in European journals. But he contributed while he was in this country to the Proceedings of the American Academy, of the American Association for the Advancement of Science, and of the Natural History Society of Boston, and to the "American Journal of Science." After his return to Europe he published papers on the "Climate of the United States, and its Effect on Habits and Manners," and on the Falls of Niagara.

In 1852 Desor accepted an invitation to Neuchâtel as professor of geology in the Gymnasium and in the Academy, and became an attractive teacher. He took a conspicuous part in the politics of Switzerland. He was a member of the Grand Council of his Canton, serving twice as its president. He was also one of the National Council, but declined the honor of presiding over it. At the same time he was pursuing his researches in geology and palæontology, and publishing the results to the world. In 1864 Desor went with Escher and Martius on a journey of exploration into North Africa, — one pregnant result reached being the conclusion that the Sahara was a former sea-basin elevated at a later epoch. Desor distinguished three kinds of deserts: erosion-deserts, sand-deserts, and those of plateaux.

Desor was one of the most active pioneers in prehistorical investigations. He made a costly collection of archæological treasures, and he published, between 1861 and 1881, eleven papers upon the subject, the last being on the fossil man of Nice. When the first International Congress of Anthropologists and Archæologists met at Neuchâtel, in 1866, he was chosen to preside. Desor owned a country-seat on the summit of the Jura, which was the resort, in the summer, of the learned from every country. The names of his famous visitors are inscribed on a tree a century old; among them that of Theodore Parker. Having given the best of his life to science, progress, and freedom, Desor bequeathed to the city of Neuchâtel his rich collections in geology and archæology, and also a large property, which he had inherited from his brother's wife, to preserve and increase them.

JOHN WILLIAM DRAPER.

John William Draper was born at St. Helen's, near Liverpool, on May 5, 1811. At the age of eleven he was sent to the school of the Wesleyan Methodists, his father being a minister in that denomination. Here and under private tutors he received his elementary education. After the University of London was opened he went there to study chemistry under Dr. Turner. At the age of twenty-two (1832), he was brought by his American relatives to the United States, where he afterwards lived, and where he died on Jan. 4, 1882, in his home at Hastings, on the Hudson. In this country he studied in the University of Pennsylvania, and in 1836 took the degree of Doctor of Medicine. He had already published original papers in the Journal of the Franklin Institute, — in 1834, on the Nature of Capillary Attraction, and on the Best Form of Galvanic Batteries; in 1835, on the Magnetic Action of Light. In 1836 the thesis presented for his degree was published by the Faculty of the University. After this, many contributions to science followed in rapid succession, — on chemistry, electricity, heat, light, thermo-electricity, phosphorescence, and kindred subjects. Fifty different papers, published in this country or in Europe, and many of them in several places, are enumerated in the Catalogue of the Royal Society of London which closes with the year 1863.

In 1837 Professor Draper began to publish his researches on the light of the sun, and on the solar spectrum, — a subject to which he often returned down to the year 1873. The discovery of Daguerre turned his attention to photography and photo-chemistry. He anticipated even Daguerre in the art of taking portraits by the action of light. But before the introduction of collodion a long exposure was necessary. As early as 1840 he obtained a photograph of the moon, about one inch in diameter, after an exposure of twenty minutes. In 1842 he announced the paradox of *latent light*, producing images invisible to the eye until revealed by chemical action upon them; whereby a new territory was annexed to the solar spectrum at the violet end, corresponding to the calorific extension at the red end. He was successful in photographing the fixed lines in the solar spectrum, outside even of its visible limits, whether formed by the dispersion of a prism or by the interference of a fine grating. His paper, in which he proved that the decomposition of carbonic acid by the leaves of plants was produced under the influence of the yellow rays rather than of the violet rays of the sun, which appeared originally in the Proceedings of the American Philosophical Society for 1843, was republished in London, Paris, and Berlin.

The results of Professor Draper's experiments on the relation of light to heat were given to the public in 1847. He proved that all solid bodies became incandescent at the same temperature, red hot at 977° Fahrenheit; and that the more refrangible rays were successively added at increasing temperatures, and the original rays became at the same time more intense. Melloni, who may be said to have created the science of radiant heat (so widely did he extend its area), was immediately attracted to these investigations of Dr. Draper, and testified to the ingenuity and success with which they had been conducted. When Kirchhoff, in 1862, published an appendix to his researches on the solar spectrum, in which he gives a mathematical foundation for experimental deductions already known, he said: "Draper has derived from experiment the conclusion that all solid bodies begin to glow at the same temperature. But he has observed in his experiments that certain bodies, as chalk, marble, and fluor-spar, shine at a lower temperature than they should according to this law: he calls this light phosphorescent, and observes that it is distinguished from the glow by its color. But whatever name may be given to the light, it contradicts the law, and a body which shows it cannot satisfy the assumption which is made in proving the law; it cannot remain unchanged, the temperature remaining the same; the phosphorescence is not the simple influence of heat, it is not exclusively conditioned on temperature, but it is caused by changes in the body: if these changes, be they chemical or of any other kind, cease, then the phosphorescence must also vanish." This quotation is introduced because it has been thought that Kirchhoff did not sufficiently recognize the value and the priority of Draper's work.

Dr. Draper's experiments on the spectra of various flames, proving that the occurrence of lines, bright or dark, was connected with the chemical nature of the substance producing the flame, brought him to the threshold of spectrum analysis, as now understood. His words are prophetic: "For this reason these lines merit a much more critical examination than has yet been given to them, for by their aid we may be able to ascertain points of great interest in other departments of science. Thus, if we are ever able to acquire certain knowledge respecting the physical state of the sun and other stars, it will be by an examination of the light they emit." If he did not himself fulfil the prophecy, Ångström and Stewart also failed, though they had come so near as to know that a gas when luminous emits rays of light of the same refrangibility as those which it has the power to absorb.

Dr. Draper's later papers (1872) on the Distribution of Calorific and Chemical Activities in the Solar Spectrum reveal a mind luminous in thought and fertile in devising experiments. His final statement is that the different rays of the sun are only distinguished by varieties of wave-length or rapidity of undulation. Whatever other differences appear do not belong to the rays, but to the bodies on which they fall, by which their energy is converted into other forms of energy. The excessive heat at and beyond the red end of the spectrum is the work of the prism, which condenses comparatively the red end and scatters the violet end. As the heat of the diffraction-spectrum was insufficient for experiment, he equalized the dispersion by collecting the rays in the focus of a curved mirror. The superiority in the chemical action at the violet end belongs to the bodies submitted to it, and disappears when they are properly chosen.

These are the fruits, not of richly-endowed scientific research, but of the intervals of leisure left by professional duties. In 1836 Mr. Draper was appointed Professor of Chemistry, Natural Philosophy, and Physiology in Hampden Sidney College, Virginia. In 1839 he was made Professor of Chemistry and Natural History in the University of New York. In 1841 he assisted in the establishment of the Medical Department of the University, was Professor of Chemistry in it, and afterwards President. A Treatise on Chemistry, first published in 1846, reached its tenth edition in 1852; another on Physiology, which appeared in 1856, arrived at its seventh edition in 1875. In 1866 he published a text-book on Anatomy, Physiology, and Hygiene. Some of the Introductory Lectures to his courses have been published; also an address before the New York Academy of Medicine, in 1863, on the "Historical Influence of the Medical Profession." His books and his lectures were vivified by his own fresh explorations into the heart of his profession: the selective action of membranes; endosmosis through thin fibres; the measure of the force of endosmosis; the cause of the coagulation of the blood; the theory of the circulation of the blood; explanation of the flow of sap; respiration of fishes; action of the organic muscle fibres of the lungs; allotropism of living systems; new observations on the action of the skin; function of nerve vessels and their electrical analogies; function of the sympathetic nerve; explanation of certain parts of the auditory apparatus, particularly of the cochlea and the semicircular canals; the theory of vision; the theory of muscular contraction — all these subjects were touched by his laborious experiments.

In 1844 Professor Draper published selections from his scientific papers under the title of "Forces Producing the Organization of Plants." Sir David Brewster, than whom no one of his day was better qualified to speak for the sun, once said to Professor Draper "that the solar spectrum is a world in itself, and that the study of it will never be completed." We have lived to see that it not only is a world in itself, but that it contains the secrets of all other worlds, and is rapidly revealing them to the patient student. In 1875 this Academy awarded the Rumford Medals to Dr. Draper for his "Researches in Radiant Energy." In 1878 he collected his scattered memoirs on this subject, and published them in a single volume of nearly five hundred pages. This publication he regarded as an autobiography of his scientific life. That the reader may not be surprised that it embodies the discoveries distilled from more than forty years of study, he reminds him that days are often required to ascertain a fact that may be stated in a single line. He says: "To a reader imbued with the true spirit of philosophy, even the shortcomings easily detectable in it are not without a charm. From the better horizon he has gained he watches his author, who, like a pioneer, is doubtfully finding his way, here travelling on a track that leads to nothing, then retracing his footsteps; and again, undeterred, making attempts until success crown his exertions." Mr. Draper appreciated the Academy's award as an acceptable return for all his disappointments and all his successes, inasmuch as it was "the highest testimonial of approbation that American science has to bestow on those who have devoted themselves to the enlargement of knowledge."

For ten years (1860 – 1870) Dr. Draper relaxed in his experimental work, and soon became a conspicuous author in the republic of letters, addressing a much larger body of readers than are reached by purely scientific works. The moral and intellectual condition of man is so intimately associated with his material organization that physiology, while dealing with the latter, cannot wholly overlook the former. By easy journeys the scientific spirit travels from man as an individual to man in his relation to different countries, races, and epochs. In 1863 Dr. Draper published "A History of the Intellectual Development of Europe." The argument of the book is that man has risen from barbarism to the highest civilization, not by accident, but by a law of growth or evolution, equally applicable to nations and individuals. This book has been translated into many European languages and Arabic, and has passed through various editions. In 1864 Dr. Draper delivered four lectures before the Historical Society of New York, which were afterwards expanded and published in 1865 under the title of "Thoughts on the Future Civil Policy of America." This book has had a large circle of readers, either in the original or in translations. It suggested a more elaborate work, viz. his "History of the American Civil War," which appeared in 1867 – 70, in three volumes. Posterity alone, it is said, can pronounce an impartial verdict on great national issues. Posterity has the advantage of knowing the results, remote as well as immediate, of important events. But it must depend for the facts on the witnesses to those events as they gradually come to light. Dr. Draper said, "More depends on the impartiality of the writer than on the deadening lapse of time." Enjoying the confidence of the Secretary of War, admitted to an inspection of the public documents on both sides, trusted by many who took a conspicuous part in the military and civil crises of the period, Dr. Draper had great advantages for writing a faithful narrative. Posterity must decide whether he has recorded the dispassionate judgments of a cool, scientific observer, or has written as a heated partisan. The last work from the pen of Dr. Draper appeared in 1874, a "History of the Conflict of Religion and Science." There is no conflict between religion and science. If he had called his subject a "History of the Conflict between Theology and Science," it would have been more intelligible, and would have disarmed much of the criticism upon it. This work has had a great circulation, having been translated into more than seven languages. Dr. Draper has shared with Galileo, Copernicus, Kepler, Locke, and Mill the honor of having his work placed on the Index of books prohibited by the Roman Church.

With such absorbing pursuits, Dr. Draper nevertheless responded to occasional calls made on his literary and scientific attainments. In 1870 he delivered an address before the American Union Academy of Literature, Science, and Art. In 1876 he spoke to the American Chemical Society of New York on "Science in America." In 1877 he addressed the Unitarian Institute at Springfield on evolution. In 1872–3 he is again in the field of scientific research, and only a few months before his death he succeeded in photographing two of the many comets which distinguished the year 1881. Dr. Draper's mind was too large to be shut up within the walls of his laboratory. To him the minutest facts were of value, but only as they furnished the key for interpreting the universal Cosmos of nature and humanity. In clear and graceful language the best that was in his thoughts was shared by the world. There was a continuity in his life-work, plain to himself, if not obvious to the superficial observer. He says: "When I thus look back on the objects that have occupied my attention, I recognize how they have been interconnected, each preparing the way for its successor. Is it not true that for every person the course of life is along the line of least resistance, and that in this the movement of humanity is like the movement of material bodies?"

LEWIS HENRY MORGAN, LL.D.

The Hon. Lewis H. Morgan was made a Fellow of the Academy in 1868. His parents were of old New England stock, and of this he often spoke with feelings of satisfaction. His father was descended from James Morgan, who settled near Boston in 1646, and his mother from John Steele, who had a home near Cambridge in 1641. At the time of his birth, Nov. 21, 1818, his parents resided in the village of Aurora, in Cayuga County, N. Y. He had the advantage of an excellent preliminary education, and was graduated at Union College in 1840. He afterwards studied law, and was admitted to the bar. Making his home at Rochester, N. Y., his zeal and honesty soon secured him a large and profitable practice in his profession. In business he was associated with his classmate, Judge George H. Danforth.

In 1855 he became interested in the projected railroad from Marquette to the iron region on the south shore of Lake Superior, and in the development of the iron mines. The management of these enterprises, from which he derived a considerable property, caused him gradually to withdraw from the practice of his profession, and induced him to make excursions into what was then the wilderness of Northern Michigan. It was during these explorations that he became interested in the habits and works of the Beaver, — a study which he followed for several years as opportunities offered, and the results of which he gave to the world, in 1868, in an octavo volume entitled "The American Beaver and his Works." This is a most thorough and interesting biological treatise, of which the late Dr. Jeffries Wyman remarked that it came the nearest to perfection of any work of its kind he had ever read.

It is however to his labors in anthropology that Mr. Morgan owes his wide-spread fame, and it is of interest to note the probable cause of his turning his attention to the study of Indian life. On his return from college he joined a secret society, known as the "Gordian Knot," composed of the young men of the village. Chiefly by his influence, this society was enlarged and reorganized, and became the "New Confederacy of the Iroquois." The society held its councils in the woods at night. It was founded upon the ancient Confederacy of the Five Nations; and its symbolic council-fires were kindled upon the ancient territories of the Mohawks, the Oneidas, the Onondagas, the Cayugas, and the Senecas. Its objects were to gather the fragments of the history, institutions, and government of the Indians and to encourage a kinder feeling towards them. A friend writes that "many of its members have since become distinguished in various walks of life, but upon none of them was its influence so persuasive and so permanent as upon Mr. Morgan. It gave direction to his thought, and stimulus to his energies. In order that it might be in conformity with its model, he visited the tribes in New York and Canada, even then remnants, but retaining, so far as they were able, their ancient laws and customs. These he investigated, and soon became deeply interested in them."

On his removal to Rochester his studies of Indian institutions were continued, and in 1846 he attended day after day a Grand Council of the Indians at the Tonawanda reservation; and in April of the same year he went to Washington to plead in behalf of the Indians against the great injustice done them in taking away some of their lands. While on this journey he attended a meeting of the New York Historical Society, of which he had been elected a member, and read his first public paper on the subject to which he had given so much time and thought. This paper is not printed in the "Proceedings of the Society," but is referred to as "an Essay on the Constitutional Government of the Six Nations of Indians." The substance of it is probably included in the series of fourteen "Letters on the Iroquois" addressed to Albert Gallatin, LL.D., the president of the society, and published in the several numbers of the "American Review,"* from February to December, 1847, under the *nom de plume* of *Skenandoah*.

These letters were followed by several instructive reports to the Regents of the University of the State of New York, upon Indian remains in that State, and on the "Fabrics of the Iroquois," all bearing evidence of his great interest and activity in the study of Indian life and institutions. These several papers were afterwards rewritten and enlarged, and published in book form in 1851, under the well-known title of "League of the Iroquois." This work at once attracted general attention, and secured for its author a well-earned position in literature. It contains a careful analysis of the social organization and government of the powerful and famous confederacy, with many details relating to Indian life.

In 1847 Mr. Morgan again attended a council of the Iroquois, and on Oct. 31, 1847, he was regularly adopted into the Hawk gens of the Senecas, and given the name of *Ta-yā-da-wah-kugh* (one lying across†), as the son of Jemmy Johnson, the interpreter, and grandson of the famous Red Jacket. As a member of the Seneca tribe he was better able than before to continue his studies of the social institutions of the remnants of the tribes forming the ancient confederacy. Ten years after this, at the Montreal meeting of the American Association for the Advancement of Science, he read a paper on "The Laws of Descent of the Iroquois," which furnished the basis of one of the most important generalizations in relation to American ethnology. In 1858, in an encampment of Ojibwa Indians at Marquette, he found that their system of kinship was substantially the same as that of the Iroquois. The conclusions which he drew from this discovery are clearly given in the paper which he read before the Academy at its meeting on Feb. 11, 1868, entitled "A Conjectural Solution of the Origin of the Classificatory System of Relationship."‡ This paper is

* The American Review: a Whig Journal of Politics, Literature, Art, and Science, vols. v. and vi. New York, 1847.

† The meaning of this name is that he was to put himself across the pathway of communication, and preserve friendship between the two races.

‡ This paper is printed in full in the Proceedings of the Academy, Vol. VII. pp. 436–477.

in fact a *résumé* of his great work which was then passing through the press, and appeared as a thick quarto volume of the Smithsonian Contributions to Knowledge, published in 1870, under the title of "Systems of Consanguinity and Affinity of the Human Family." This volume is literally one of facts, from which most important conclusions are constantly being drawn. As Mr. Morgan states, it contains the systems of relationship of "four-fifths, numerically, of the entire human family."

During the years in which these materials were being collected Mr. Morgan was not idle, but was gradually obtaining information for future contributions, both by study in his well-stored library and by personal expeditions among the Indian tribes of the West and of Hudson Bay Territory. This also was the most active period of his literary life, several of the papers which were afterwards revised and printed having been sketched during this time. Among the most important of these were contributions to the "North American Review," from 1869 to 1876, under the titles of "The Seven Cities of Cibola," "Indian Migrations," "Montezuma's Dinner," and the "Houses of the Mound-Builders." Probably the paper of 1876, entitled "Montezuma's Dinner," is the most characteristic of what has been called the "Morgan school" of ethnology. In it he showed that the commonly received statements relating to the Aztec civilization were founded on misconceptions and exaggerations, and that the Mexican confederacy, reviewed in the light of knowledge derived from a study of the social and tribal institutions of the Indians of America, would be found to form no exception to the democratic military and priestly government founded on the gentile system common to the American tribes.

Mr. Morgan always chose forcible language in expressing his ideas, and he held fast to theories which he believed to be well founded. The recent extended investigations which have brought many additional facts to light will naturally lead to the criticism of some of the theories which he formed, from the facts at his disposal, during the active period of his literary work; but while such as were constructed of loose materials will fall, and none would have been more ready than he to pull them down in the cause of truth, the great principles which his researches have brought out are so apparently beyond controversy that they will ever stand as the rocks against which the wild and sensational theories will be dashed, and as foundations upon which to build in the further study of American archæology and ethnology.

Mr. Morgan's last excursion was to the ancient and modern pueblos of Colorado and New Mexico in 1878, and was undertaken primarily for the purpose of confirming his conceptions in relation to the development of house life among the Indian tribes. In "House Life and Architecture of the North American Indians," expressing his views of communal living among the village Indians, we particularly notice the persistency with which he clung to his early theories on this subject. This was his latest work, published only a few weeks before his death.

While his "Systems of Affinity and Consanguinity," "League of the Iroquois," and paper on the Mexican civilization will ever stand as monuments of his industry and research, and give to him enduring fame, he will be most widely known by his more popular volume of 1877, "Ancient Society, or Researches in the Lines of Human Progress from Savagery, through Barbarism, to Civilization," which is, in fact, the embodiment of the most important of his researches, the grand summing up of many years of industrious labor and deep thought. A thorough evolutionist in his treatment of the subjects of his volume, he commences the Preface with the statement that "The great antiquity of mankind upon earth has been conclusively established," and goes on to state that "this knowledge changes materially the views which have prevailed respecting the relations of savages to barbarians, and of barbarians to civilized men. It can now be asserted upon convincing evidence that savagery preceded barbarism in all the tribes of mankind, as barbarism is known to have preceded civilization. The history of the human race is one in source, one in experience, and one in progress." He then on the second and third pages writes, that "Inventions and discoveries stand in serial relations along the lines of human progress and register its successive stages, while social and civil institutions, in virtue of perpetual human wants, have been developed from a few primary germs of thought. They exhibit a similar register of progress. . . . Throughout the latter part of the period of savagery, and the entire period of barbarism, mankind in general were organized in gentes, phratries, and tribes. . . . The principal institutions of mankind originated in savagery, were developed in barbarism, and are maturing in civilization. In like manner the family has passed through successive forms, and created great systems of consanguinity and affinity, which have remained to the present time. . . . The idea of property has undergone a similar growth and development. Commencing at zero in savagery, the passion for the possession of property, as the representative of accumulated subsistence, has now become dominant over the human mind in civilized races." He then writes that "The four classes of facts above indicated, and which extend themselves in parallel lines along the pathways of human progress from savagery to civilization, form the principal subjects of discussion in this volume."

These quotations are sufficient to convey an idea of the substance of the volume and the principles which its author has set forth. To follow his scholarly statements and call attention in detail to the important deductions he has drawn, particularly in relation to American ethnology, would be impossible in this brief notice of the labors of one who has done so much.

In social life Mr. Morgan was much beloved for his kind and genial ways, and at Rochester his house, with its large hall, in which were his library and collections, was often the gathering place of scholars and scientists, and there the well-known literary Club, of which he was one of the founders a quarter of a century ago, often met to discuss the papers which he brought before them. Ever active as a citizen in all good works, he was twice honored by public offices: in 1861 he was a member of the State Assembly, and in 1867 he was a Senator. In both these capacities he was distinguished as the uncompromising foe of all vicious measures, and his fair name was never sullied by even the insinuation of corrupt or double dealing.

From his great interest in the Indian tribes and from his knowledge of the natural course of the development of civilization, he always took to heart the unfortunate condition of the Indians and the unnatural methods which were pursued by Government in relation to their civilization, and often urged, as occasions arose, the desirability of leading the Indians to civilization by making them self-sustaining as a pastoral people, writing several letters to the press, particularly to the "Nation," in which are presented forcible reasons for following such a plan.

Mr. Morgan was a member of numerous historical and scientific societies, and in 1879 he was elected President of the American Association for the Advancement of Science, and presided over the meeting held in Boston the following year. At this time it was noticed that his strength was failing, and, although he had much enjoyment at the meeting, he remarked that it would probably be the last time he should meet with the Association, and that he so much the more appreciated the honor which had been conferred upon him. From that time he slowly declined, and died at his home, at the age of sixty-three, on Dec. 17, 1881.

Mr. Morgan was married in 1851 to Mary E., daughter of the late Lemuel Steele, of Albany, N. Y., who, with one son, survives him.

A sad calamity caused the death of his two daughters in 1862, and at that time, as Mr. Morgan was much interested in plans for the higher education of women, he endeavored to establish in Rochester a college for women, to which he proposed to make a memorial endowment; but his efforts were not entirely successful. He then resolved to leave the whole of his property for the purpose after the decease of his wife and son, hoping that others would unite in making the fund ample for such an institution. In pursuance of this object he has left his entire and considerable property in trust to the University of Rochester for the final establishment of a college for women.

In the "Popular Science Monthly" for November, 1880, there is a good portrait of Mr. Morgan as President of the American Association for the Advancement of Science, accompanied by an account of his life written by Major J. W. Powell.

In this short sketch no attempt has been made to mention all the publications of which Mr. Morgan was the author. A full list of his papers is desirable, as they are widely scattered, and several are but little known, and difficult to obtain. The following list gives the titles of those which have come under the writer's notice: —

Letters (1–14) on the Iroquois, "by Skenandoah," addressed to Albert Gallatin, LL.D., President of the New York Historical Society. (The American Review: a Whig Journal of Politics, Literature, Art, and Science. Vols. v., vi. February–December, 1847.) New York. 8°.

Communications to the Regents of the New York State University: An Account of Indian Pipes, Fortifications, &c., in New York, 1848. (Second Annual Report of the Regents of the University of the State of New York.) 1849. Albany. 8°. Illustrated.

Report upon the Articles furnished the Indian Collection, 1849. (Third Annual Report of the Regents of the University of the State of New York.) 1850. Albany. 8°. Illustrated.

The Fabrics of the Iroquois. (Reprint in part of Report to the Regents of the New York State University. Stryker's American Register and Magazine. July, 1850. Vol. iv.) Trenton. 8°. Illustrated.

Schedule of Articles obtained from the Indians in Western New York and on Grand River, Canada. Abstract of Report. (Third and Fifth Annual Reports of the Regents of the University on the State Cabinet of Natural History.) Albany, 1850, 1852. 8°.

League of the Ho-dé-no-sau nee, or Iroquois. Rochester, 1851. 8°. Illustrated.

Report on the Fabrics, Inventions, Implements, and Utensils of the Iroquois. (Fifth Annual Report of the Regents of the State of New York, 1851.) Albany, 1852. 8°. Illustrated.

List of [198] Articles manufactured by the Indians of Western New York and Canada West, with their Indian names. (Catalogue of the Cabinet of Natural History of the State of New York.) Albany, 1853. 8°.

Laws of Descent of the Iroquois. (Proceedings of the American Association for the Advancement of Science. Montreal Meeting, 1857.) Vol. xi. Cambridge, 1858. 8°.

The Indian Mode of Bestowing and Changing Names. (Proceedings of the American Association for the Advancement of Science. Springfield Meeting, 1859.) Vol. xiii. Cambridge, 1860. 8°.

Circular in Reference to the Degrees of Relationship among Different Nations. (Smithsonian Miscellaneous Collections. Vol. ii.) 1860. 8°.

Suggestions relative to an Ethnological Map of North America, 36 by 44 inches. (Annual Report of the Smithsonian Institution for 1861.) 1862. 8°.

A Conjectural Solution of the Origin of the Classificatory System of Relationship. (Proceedings of the American Academy of Arts and Sciences, February, 1868.) Vol. vii. Boston, 1868. 8°.

The American Beaver and his Works. Philadelphia. 1868. 8°. Illustrated.

The "Seven Cities of Cibola." (North American Review. Vol. cviii. April, 1869.) Boston, 1869. 8°.

Indian Migrations. (North American Review. Vol. cix. Oct., 1869; Vol. cx. Jan., 1870.) Boston, 1869, 1870. 8°.

The Stone and Bone Implements of the Arickarees. (Twenty-first Annual Report of the Regents of the University of the State of New York on the State Cabinet of Natural History, 1868.) Albany, 1871. 8°. Illustrated.

Systems of Consanguinity and Affinity of the Human Family. (Smithsonian Contributions to Knowledge. 218.) Washington, 1871. 4°.

Australian Kinship. From Original Memoranda of Rev. Lorimer Fison. (Proceedings of the American Academy of Arts and Sciences, March, 1872. Vol. viii.) Boston, 1873. 8°.

Ethnical Periods. (Proceedings of the American Association for the Advancement of Science. Detroit Meeting, 1875.) Vol. xxiv. Salem, 1876. 8°.

Arts of Subsistence. (Proceedings of the American Association for the Advancement of Science. Detroit Meeting, 1875.) Vol. xxiv. Salem, 1876. 8°.

Houses of the Mound-Builders. (North American Review. Vol. cxxiii. July, 1876.) Boston, 1876. 8°.

Montezuma's Dinner. (North American Review. Vol. cxxii. 1876.) Boston, 1876. 8°.

Ancient Society, or Researches in the Lines of Human Progress from Savagery through Barbarism to Civilization. New York, 1877. 8°.

On the Ruins of a Stone Pueblo on the Animas River in New Mexico: with a Ground Plan. (Twelfth Annual Report, Peabody Museum of American Archæology and Ethnology.) Cambridge, 1880. 8°.

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ST. JULIEN RAVENEL, M.D.

Dr. St. Julien Ravenel, whose death occurred on March 15, 1882, was no ordinary man. With large scientific knowledge and a mind eminently qualified for scientific research, he joined the ardor of the speculative philosopher to a patience in experiment and inquiry which never failed. There was in the changed conditions of agriculture in his native State and in the South a vast arena for the exercise and application of scientific investigation. There was his chosen work.

The origin and rapid development of the manufacture of commercial fertilizers in South Carolina; the simplification of the modes of manufacturing fertilizers so as to lessen the cost and enlarge the area of consumption; the discovery of a system by which small grain and hay can be grown in profusion on the worn-out and sandy lands of the Carolina coast; a mode of turning to immediate account the lands which, it was thought, must be abandoned if ever the culture of rice should become unprofitable; the use of artesian wells in and around Charleston for supplying mills and factories with water at an inconsiderable expense, — all these are inseparably connected with the name of Dr. St. Julien Ravenel.

Dr. St. Julien Ravenel, the eldest son of the late John Ravenel, was born in Charleston, S. C., on December 15, 1819, where he received his early education in the grammar-schools of that city. Subsequently he went to New Jersey to continue his studies, and finally applied himself to medicine. He was a student with Drs. Holbrook and Ogier, and was graduated at the Medical College in Charleston in the class of 1840. Afterwards he continued the study of medicine at Philadelphia and in Paris. Upon his return to Charleston he became Demonstrator of Anatomy at the Medical College, but resigned the position after a time. The active practice of medicine was distasteful to him, although he had the promise of a highly successful career.

He now determined to devote his life to scientific pursuits. He became intimate with the late Professor Agassiz, and was associated with him in his investigations. Dr. Ravenel pursued with especial interest the study of natural history and physiology, being particularly skilful in microscopic researches. Chemistry, however, was his favorite pursuit, and in chemistry as applied to agriculture he achieved his most important results. When the war broke out he went into service with the Phœnix Rifles, and was with that command at the bombardment of Fort Sumter. Somewhat later he was assigned to duty at Columbia. After the war he returned to Charleston, and upon the discovery of the value of the phosphate deposits of South Carolina for agricultural purposes he founded one of the phosphate companies, and remained identified to the close of his life with various chemico-agricultural companies in South Carolina.

It was Dr. Ravenel who some years ago raised new hopes in the whole low country of South Carolina by the explanation of means by which large crops of small grain and hay could be made on the light sandy lands on the coast, and he had so demonstrated the practicability of his views that a company is in progress of formation with the object of commencing operations on the delta of the Santee River.

Dr. Ravenel took great interest in the effort to secure to Charleston an abundant supply of pure water. He closely watched the boring of the first artesian well, and one effect of his observations was the boring of artesian wells of moderate depth for the use of mills and factories.

When the yellow fever ravaged Norfolk, he was one of the band of volunteers who went from Charleston to the relief of that unfortunate city. As surgeon-in-chief of the large Confederate hospital in Columbia, he won the admiration of the citizens not more by his skill than by his kindness.

By the death of Dr. Ravenel Charleston loses one of her most devoted and eminent sons, who has perhaps done more to develop the native resources of South Carolina than any other single individual.

ADMIRAL JOHN RODGERS.

John Rodgers, U. S. Navy, was born in Hartford County, Maryland, Aug. 8, 1812. His paternal grandfather was a lieutenant-colonel in the Revolutionary War, and served with credit in command of Maryland troops. His father was Commodore John Rodgers, the well-known naval commander of the early part of the present century. The subject of the present sketch was appointed a midshipman in the Navy in 1828, and found his first duty in the Mediterranean squadron on board the ship Constellation. After passing his examination in 1834, he desired to obtain a better education than was practicable on board ship, and therefore secured a year's leave of absence, which he spent at the University of Virginia. During the five years following, his life was the usual one of the naval midshipman of the best class. He served for a short time on coast-survey duty. On Jan. 22, 1840, he was promoted to the grade of lieutenant, and assigned, first to the command of the schooner Wave, and afterward to that of the brig Jefferson. His station was now the coast of Florida, where he was actively engaged in the war with the Seminole Indians. After another tour of duty in the Mediterranean squadron, and spending two years at Pittsburg, Pa., he was again detailed for coast-survey service and sent to investigate the hydrography of the coast of Florida. He executed this work with a skill which elicited the warm encomiums of Professor Bache, and laid the foundation of his subsequent reputation.

The first duty which brought him prominently before the public was the command of the North Pacific Survey Expedition. The object of this expedition was the survey of the islands on the north-eastern coast of Asia, from Japan to Behring Strait. The commander of the expedition at the time she sailed was Ringgold; but on reaching the coast of Japan ill health obliged him to resign the command, which then devolved upon Lieutenant Rodgers. During the following three years his squadron was employed in the duty assigned to it, and made the most complete survey that had ever been attempted by an American squadron in those waters. In 1855 he made his celebrated expedition in the Vincennes through Behring Strait, with a view of continuing his explorations into the Arctic Ocean. He especially desired to verify the positions of certain lands which had been reported as north of Herald Island. The northern-most point which he reached was 72° 5′ of latitude, and the supposed land was not found. He then turned his course toward the west, with a view of exploring Wrangel Land, but ice compelled him to retrace his steps. His return through Behring Strait was marked by a line of soundings which had the effect of rendering navigation safer for future expeditions. His whole conduct of this difficult expedition was marked by a skill, fortitude, and prudence which assured him a commanding position in the public service. He reached San Francisco on his return in October, 1855, and was immediately promoted to the grade of commander.

During the five years after his return he spent most of his time in Washington, engaged in preparing the work of his expedition for the press. This duty was finished about the time of the outbreak of the Civil War. The services of our colleague during the war are so well known that little more than a brief description of their character and of the qualities which they displayed will be necessary.

He was first assigned to duty on the Mississippi in building and organizing the fleet of iron-clads which afterward did such distinguished service under Admirals Foote and Davis. Before completing the work he was ordered to the Atlantic coast, and accompanied Admiral Dupont as aid in the expedition against Port Royal. It was he who there hoisted the American flag on the captured forts. He was next placed in command of the iron-clad sloop-of-war Galena. During the year which he spent on this ship she was stationed in or near the James River. Her commander seems to have had great faith in the efficiency of iron-clads as fighting ships, and to have lost no opportunity of testing them against shore batteries. His attack on Fort Darling was one of the most gallantly-conducted naval engagements of the war, two-thirds of his crew being killed or wounded.

Toward the end of 1862 he was detached from the Galena, ordered to the command of the Monitor Weehawken, and sent to the South Atlantic blockading squadron. His capture of the Rebel irod-clad Atlanta near Savannah, Ga., was one of the remarkable events of the war, owing to the proof it gave of the power of heavy shot against such armored vessels as then existed. The Atlanta was supposed to be the most powerful iron-clad which the Confederate Government had built, and when she put to sea for the purpose of destroying the monitors of the blockading squadron, she was followed by a steamer filled with spectators. But the first shot from the fifteen-inch gun of the Weehawken, although it did not actually pass through her side, produced a concussion which so stunned and disabled the crew that they speedily surrendered.

After the close of the war the question arose whether the monitors were adapted to long voyages. Commodore Rodgers offered to test the question by conducting the Monadnock to San Francisco through the Straits of Magellan, he keeping her company in the Vanderbilt. This duty he performed with entire success during the years 1865 and 1866.

After three years on shore duty, he was assigned to the command of the Asiatic squadron. Here his most noteworthy act was the chastisement of the Coreans on account of their outrages against the American merchant flag. Their authorities refusing to make any satisfactory reply to his demands, he planned an attack on their forts, which were first bombarded and then carried by assault.

After another tour of shore duty he was assigned in 1877 to the superintendency of the Naval Observatory. It is here that his work has most interest for this Academy. He devoted himself to his new duties with characteristic zeal and energy. It was a part of his general policy to interest the astronomers of the country at large in the work of the establishment, and he accordingly sought their aid and counsel on all occasions where their co-operation was conducive to the object in view. He took especial interest in the approaching transit of Venus, and was president of the commission appointed to provide for observations upon it. His greatest work during his term of office was the planning of the new observatory. Finding the locality in which the observatory was situated so unhealthy that it was impossible to secure the highest efficiency in its work, as well as unsuitable in other respects, he immediately began to urge upon Congress the necessity for removing it to a better locality. Such a removal had been previously discussed, but no such energy had ever been devoted to it as was exhibited by the new superintendent. The opinions of professors and physicians were obtained, showing the necessity for a removal, and the representations of the Superintendent were received with such favorable consideration that he hoped for an immediate execution of the plan. Obstacles, however, presented themselves at every step. The report of the first commission appointed to select a site was rejected and a new commission formed. A site suitable in every respect was at length acquired by the Government in 1881, and our colleague had every prospect of seeing the establishment of an institution with which his name would have been inseparably associated. But before anything could be done towards commencing the building unmistakable signs of failing strength began to show themselves. In the spring of 1882 his health rapidly gave way, and on May 5, he succumbed to disease.

Admiral Rodgers possessed in a remarkable degree all those qualities which have done so much to give our military and naval service its present high position in the confidence of the nation. His general bearing was that of power in repose, and suggested the philosophic thinker as much as the naval commander. He seemed an entire stranger to passion or excitement of any kind. His sentences were slow and measured, and it is stated by those who fought at his side that in the highest excitement of battle his speech and manner were as cool and collected as in every-day life.

BARNAS SEARS, D.D.

In Saratoga, N. Y., July 6, 1880, Barnas Sears * closed a long life of public usefulness. For more than fifty years he had done distinguished service in various departments of education, and had won an honorable name in literature and in the pulpit. Like many eminent leaders in political and professional life, he was born in the country (Sandisfield, Mass., Nov. 19, 1802) and was bred upon a farm, and his fine physique and well-poised character owed much to the bracing air and grand scenery of the Berkshire Hills.

The work of the farm was agreeable, and stirred an honest pride in outdoing his older brothers; but he early felt that he was called to a broader life, and must follow public rather than private aims. At fifteen years of age he bought his freedom from his father, and set up for himself; with characteristic energy, employing a man and a team to assist him in building stone walls. In the winter he taught in district schools, and industry with thrift soon gathered the resources needed for his liberal education. He graduated with honor at Brown University in 1825, but deliberately sacrificed the first place in his class to the pursuit of studies not included in the curriculum.

After leaving college he entered Newton Theological Institution, and was one of the three members of its first graduating class in 1827. He was called immediately to the pastorate of the First Baptist Church, Hartford, and in a brief term of service gave promise of winning a foremost place among American preachers. But discerning friends recognized in him rare gifts for teaching, and as his own tastes inclined more to study than to pastoral work, he accepted, in 1829, the Chair of Ancient Languages in the Literary and Theological Institution at Hamilton, N. Y. He entered on his work with enthusiasm, but soon felt the need of broader culture and better helps than could be furnished by American scholarship, and was one of the first students from the United States to seek the advantages of German universities. He spent two years at Berlin and Leipsic and Halle, and was grateful to the end of life for the inspiration received from German teachers, and especially from Tholuck and Neander. He returned to Hamilton in 1835, but after a few months removed to Newton to fill the Chair of Christian Theology to which he had been elected. For twelve years he was connected with this institution, during the

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* Notice omitted in Volume XVI.

larger part of the time as its president, and won the enthusiastic love of his pupils as a teacher of singular magnetism and inspiration.

In 1848 he resigned his position to accept the secretaryship of the Massachusetts Board of Education. It was a critical time in the educational history of the State. The Hon. Horace Mann, his predecessor, had introduced bold and radical changes into the school system, and by energy and decision in pushing the changes had aroused a vigorous opposition. The success of the reforms was in great peril. But Dr. Sears, by his conciliatory spirit, by patience in hearing objections and broad wisdom in answering them, soon silenced opposition, and introduced other important changes.

In 1855 he was elected President of Brown University, and removed to Providence to enter on the duties of his new office. The difficulties encountered were many and complicated. His predecessor, Rev. Dr. Wayland, had a national reputation as the most eminent of American presidents, and for nearly thirty years had moulded the character and aims of the college by his energetic will. The Faculty and Corporation were in warm sympathy with his views and methods. Dr. Sears had different views and methods, but could introduce them only slowly, and with wise caution and tact. His administration, however, was eminently successful, and the growth of the college was marked in an increase of students, in a broadening of the range of study, and in the enlarging of its endowment. Dr. Sears was a popular president in the best sense of the word, beloved by the students as a teacher and as an administrator, and ruling less by prescribed law than by moral force.

After twelve years of hard labor, in which his health suffered and his voice failed from a severe bronchial trouble, his physician prescribed rest from teaching as an imperative duty. He had intended to spend a year in European travel and study; but he was urgently requested by Mr. Peabody and the Board of Managers of the Peabody Fund to assume the duties of the general agency in administering that great trust. He had previously submitted to the board, at the request of the Hon. Robert C. Winthrop, its president, a plan of operation in the Southern States which commanded a unanimous approval, and it was thought he would prove the best executor of his own plan. He accepted the trust, removed to Staunton, Va., and the last thirteen years of life were devoted to the establishment of a system of free schools in the Southern States. This was probably the most useful part of his life. His commanding person and genial manners and high character brought him into pleasant relations with the leaders of Southern society, while his broad learning and intuitive tact gave him a controlling influence in removing old prejudices or introducing new measures. He was always heard with deference by the members of State legislatures; his advice was welcomed by statesmen and scholars and educators, and he was a universal favorite in social circles of every grade. At his death the first part of his plan for administering the trust was considered by the board as accomplished; the system of free schools was established in every Southern State. The board were prepared to carry out the second part of the plan, the elevation of the standard of education through normal schools of a high grade. Mr. Winthrop, in a tribute of rare beauty at the funeral services, which was the more welcomed because wholly unpremeditated, said with tenderest pathos: "I am expressing the feelings of my colleagues, no less than my own matured judgment, when I say, that neither among the living nor the dead do we know the man who could have discharged the delicate and responsible duties of this important trust with more conscientious fidelity or greater success."

Dr. Sears was married, Feb. 16, 1830, to Elizabeth Griggs Corey, of Brookline, Mass., who survives him with four children, three sons and a daughter.

He received the honorary degree of Doctor of Divinity from Harvard University in 1841, and the honorary degree of Doctor of Laws from Yale College in 1862. He was for many years the editor of the "Christian Review," and an associate editor of the "Bibliotheca Sacra," contributing valuable literary and theological papers to these and other periodicals. He published a "Life of Luther," which had a wide circulation in this country and in England; and in connection with Profs. E. A. Park and B. B. Edwards prepared a volume on "Classical Studies." He edited an American edition of Nöhden's German Grammar and of Roget's "Thesaurus," with many additions for American students; and prepared a volume called "Ciceronia," with extracts from Cicero and an account of the Prussian method of classical instruction; also "Select Treatises of Martin Luther," with philological notes, and essays on English and German etymology. He was an active and useful member of many learned societies, and a cordial worker in religious and philanthropic institutions.

FOREIGN HONORARY MEMBERS.

JOHANN KASPAR BLUNTSCHLI.

Johann Kaspar Bluntschli, elected a Foreign Honorary Member of this Academy in 1868, was born at Zürich, March 7, 1808, and died at Heidelberg, Oct. 21, 1881. Being unwilling to conform with his mother's wish that he should become a minister of the gospel, he entered the Political Institute of Zürich, where history, philosophy, public law, and political economy were taught. After spending some time here, he went to Germany in 1827, gained a prize at Berlin on a question touching the Roman law of succession, and sustained an examination at Bonn for a doctorate in 1829. Returning to his native town, he began to teach Roman law in the Institute; and in 1833, on the opening of the University of Zürich, he was there appointed a professor in that branch, and held some offices connected with the courts. In 1837 he was chosen to be a deputy to the Grand Council of the Swiss Confederation, and in an agitated time took the Conservative side against the Radicals. From 1839 to 1846 he was one of the leaders of that party, and represented its political views in the Diet.

His career as a writer began in this first period of his academical life, while he yet remained in his native city. He made his *début* by publishing his "Staats- und Rechtsgeschichte der Stadt und Landschaft Zürich," which saw the light in 1838–1839, and went into a second edition in 1856. In the year 1839 he gave to the world also an essay entitled "Die neuere Rechtsschulen der deutschen Juristen," in which he strove to show the importance of uniting the historical and philosophical methods of treating jural science. In 1846–49 he published the first volume of his "Geschichte des schweizerischen Bundesrechts von den ersten ewigen Bünden bis auf die Gegenwart." The second volume, containing documents, followed in 1852. A less important work in 1844, entitled "Psychologische Studien über Staat und Kirche," compared the periods of human life with those of states. The infancy of states is radicalism; their youth, liberalism; their mature age is conservative; their old age, absolute. And to this questionable theory he returned more than once afterward.

In his public and political life, while he remained in Switzerland, he seems to have steered a middle course between the Conservative and the Radical parties, hoping to form a Conservative-Liberal centre able to resist extremes in either direction. But the Radicals and Ultramontanes were too strong, as they had been before. He strove also to reform the Federal pact in a centralized direction, but without success. Meanwhile he removed to Munich, and in 1848 became professor in the university there of German private law and general public law. Here he remained fourteen years outside of politics, devoting his life more exclusively than he had hitherto done to the career of an author in his department. A labor laid upon him while he was yet at Zürich, that of codifying the *Privatrecht* of the canton, now demanded his attention. The first portion of the code, which had been finished in 1844, embraced the rights of persons, of the family and of succession; the part relating to property appeared in 1851; that touching obligation in 1853 and afterward. This code is regarded as one of the most noteworthy legislative works of our times. It served as a model for codes in other Swiss cantons.

In 1852 M. Bluntschli published his "Allgemeines Staatsrecht geschichtlich gegründet," which, after passing through four editions, was transformed into a tripartite work with the titles "General Doctrine of the State," "General Rights of the State," and "Politics." This he regarded as a terminal work of a life consecrated to legal science and practice. The little volumes of "Deutsches Privatrecht," 1856, which went through three editions in German and were translated into French, show how fruitful he was at this time as an author. Another enterprise of his was a critical review for legislation and jurisprudence, which is still issued as the Critical Quarterly. Soon after this undertaking he planned the "Staatswörterbuch," in which many distinguished Germans co-operated with him. Eleven volumes of this lexicon appeared between 1857 and 1870, and subsequently an abridgment was made by another hand.

In 1860 M. Bluntschli, in concert with other jurists, formed a union called the "Juristentag," which aimed not only at objects pertaining to juristic science, but also at cultivating the spirit of unity in the German nation. He was twice the presiding officer, in 1861 and 1868. One important matter which the jurists wished to effect was uniform legislation throughout the German States in regard to the departments of obligation, penal law, and civil procedure. But the States could not be made to agree on the mode of bringing this about, and the results did not answer to the hopes of the members.

During the years of his residence in Bavaria, M. Bluntschli transferred his main interest from civil to public law; and at this time also his feelings changed from Conservatism to broader political sympathies.

Yet he never left his first political direction so far as to become a Radical. He was treated with great consideration by the King of Bavaria, and his relations were friendly to the distinguished men around him. Still he wanted a sphere of more practical action than Bavaria could furnish. He accordingly accepted a professorship of political science in the University of Heidelberg, which Robert von Mohl had just resigned in order to represent the Grand Duchy of Baden in the Reichstag. This post he filled from 1861 to his death.

From the time of his removal to Heidelberg onward there was a new tendency given to his studies; henceforth international law, to which he had hitherto paid no great attention, absorbed his chief interest. M. Alphonse Rivier, the general secretary of the Institut de Droit International, — to whose obituary notice of Bluntschli in the "Revue du Droit International" we have been very deeply indebted in preparing this memoir, — speaks of him as he advanced in years in terms like these: "Instead of contracting himself, as so many do, with the advance of age, this noble intellect developed itself incessantly in height and breadth. *From the law of Zürich* he had passed forward to *Swiss law*, then to *German*, then to *law in general*. Henceforth *international* law will be his favorite study; and to this he will join a tendency to 'vulgarization' in the elevated meaning of that word [that is, the bringing of the results of his study more within the reach of the common mind]. He has been reproached for this; it has been looked upon as a lowering of his talents. I look on it rather from a contrary point of view; and when in the decline of life a prince of science and of thought seeks to bring his treasures within the reach of the small and of the weak, he seems to me to do a work of self-denial of which a refined soul alone is capable."

The first-fruits of this new direction in his studies was his "Moderne Völkerrecht der civilisirten Staaten, als Rechtsbuch dargestellt," 1868, or "Modern International Law Codified." This was prefaced by a letter to Dr. Lieber, whose rules of war, prepared in 1863, and entitled "Instructions for the Government of Armies of the United States in the Field," he thought very highly of, and has inserted in his own work as an appendix. This work of his was translated into French, Spanish, and Chinese, and passed through three editions in Germany between 1868 and 1878. Being constructed in the form of a code with occasional annotations, it was capable of condensation and precision; but the form exposed the author occasionally to the making of international rules of his own. A number of smaller works we will mention here together with the years when they first came to light: "Das moderne Kriegsrecht der civilisirten Staaten," 1868; "Das Beuterecht im Krieg"; "Das Seebeuterecht ins besondere," 1878; "Geschichte des allgemeinen Staatsrecht und der Politik," 1864; "Deutsche Staatslehre für Gebildete," 1875; besides many brochures, as "The Right of War and the Usage of War," "Question of the Alabama," "Quality of a Citizen, from the Point of View of International Relations"; articles "On the Congress of Berlin," "On the Pope's Responsibility and Irresponsibility according to International Law"; a legal opinion "On the Condition of the Jews in Roumania." A number of editions, also, of earlier works, some of them considerably enlarged, appeared in this period.*

To M. Rolin-Jacquemyns of Belgium, and M. Bluntschli especially belongs the credit of founding the Institut de Droit International, which enrolls on its list of members honored names from almost all countries where international law is studied. Bluntschli was one of its most active members,—a learned and able reporter of subjects referred to its committees, its president and vice-president on several occasions. At the meeting of 1880 at Oxford he received the Doctorate of Civil Law from that University.

Laborious studies did not prevent a man so highly esteemed from being called to discharge public duties as a citizen; as a member of the legislative body in Baden; as a delegate from the German Empire to the (unhappily abortive) Congress at Brussels for regulating the laws and usages of war. He also took an interest in the religious affairs of his adopted country. And here we may say that through life he had been a Christian believer; and that "though he could hold neither the doctrine of Calvin nor that of Zwingle nor that of Luther, he often avowed his attachment to the fundamental principles of Christianity." He was an active member of the Synod of Baden; and, as its president, was in the act of closing the session with the words of scripture, "Glory to God in the highest, peace on earth, and goodwill to men," when an attack of apoplexy caused his death in his seventy-fourth year. Few jurists, few publicists of our age have deserved so honorable a mention as he.

* These and many others not spoken of here may be found at the end of the catalogue of his library, which his family offers for sale *en masse*.

CHARLES DARWIN.

Charles Darwin died on the 19th of April last, a few months after the completion of his 73rd year; and on the 26th, the mortal remains of the most celebrated man of science of the nineteenth century were laid in Westminster Abbey, near to those of Newton.

He was born at Shrewsbury, Feb. 12, 1809, and was named Charles Robert Darwin. But the middle appellation was omitted from his ordinary signature and from the title-pages of the volumes which, within the last twenty-five years, have given such great renown to an already distinguished name. His grandfather, Dr. Erasmus Darwin, — who died seven years before his distinguished grandson was born, — was one of the most notable and original men of his age; and his father, also a physician, was a person of very marked character and ability. His maternal grandfather was Josiah Wedgwood, who, beginning as an artisan potter, produced the celebrated Wedgwood ware, and became a Fellow of the Royal Society and a man of much scientific mark. The importance of heritability, which is an essential part of Darwinism, would seem to have had a significant illustration in the person of its great expounder. He was educated at the Shrewsbury Grammar School and at Edinburgh University, where, following the example of his grandfather, he studied for two sessions, having the medical profession in view, and where, at the close of the year 1826, he made his first contribution to natural history in two papers (one of them on the ova of Flustra). Soon finding the medical profession not to his liking, he proceeded to the University of Cambridge, entering Christ's College, and took his bachelor's degree in 1831; that of M.A. in 1837, after his return from South America.

It is said that Darwin was a keen fox-hunter in his youth, — not a bad pursuit for the cultivation of the observing powers. There is good authority for the statement — though it has nowhere been made in print — that at Cambridge he was disposed at one time to make the Church his profession, following the example of Buckland and of his teacher, Sedgwick. But in 1831, just as he was taking his bachelor's degree, Captain Fitzroy offered to receive into his own cabin any naturalist who was disposed to accompany him in the Beagle's surveying voyage round the world. Mr. Darwin volunteered his services without salary, with the condition only that he should have the disposal of his own collections. And this expedition of nearly five years — from the latter part of September, 1831, to the close of October, 1836 — not only fixed the course and character of the young naturalist's life-work, but opened to his mind its principal problems and suggested the now familiar solution of them. For he brought back with him to England a conviction that the existing species of animals and plants are the modified descendants of earlier forms, and that the internecine struggle for life in which these modifiable forms must have been engaged would scientifically explain the changes. The noteworthy point is that both the conclusion and the explanation were the legitimate outcome of real scientific investigation. It is an equally noteworthy fact, and a characteristic of Darwin's mind, that these pregnant ideas were elaborated for more than twenty years before he gave them to the world. Offering fruit so well ripened upon the bough, commending the conclusions he had so thoroughly matured by the presentation of very various lines of facts, and of reasonings close to the facts, unmixed with figments and *à priori* conceptions, it is not so surprising that his own convictions should at the close of the next twenty years be generally shared by scientific men. It is certainly gratifying that he should have lived to see it, and also have outlived most of the obloquy and dread which the promulgation of these opinions aroused.

Mr. Darwin lived a very quiet and uneventful life. In 1839 he married his cousin, Emma Wedgwood, who with five sons and two daughters survives him; he made his home on the border of the little hamlet of Down, in Kent, — "a plain but comfortable brick house in a few acres of pleasure-ground, a pleasantly old-fashioned air about it, with a sense of peace and silence;" and here, attended by every blessing except that of vigorous health, he lived the secluded but busy life which best suited his chosen pursuits and the simplicity of his character. He was seldom seen even at scientific meetings, and never in general society; but he could welcome his friends and fellow-workers to his own house, where he was the most charming of hosts.

At his home, without distraction and as continuously as his bodily powers would permit, Mr. Darwin gave himself to his work. At least ten of his scientific papers, of greater or less extent, had appeared in the three years between his return to England and his marriage; and in the latter year (1839) he published the book by which he became popularly known, viz., the "Journal of Researches into the Natural History and Geology of the Countries visited during the Voyage of the Beagle," which has been pronounced "the most entertaining book of genuine travels ever written," and it certainly is one of the most instructive. His work on "Coral Reefs" appeared in

1842, but the substance had been communicated to the Geological Society soon after his return to England; his papers on "Volcanic Islands," on the "Distribution of Erratic Boulders and Contemporaneous Unstratified Deposits in South America," on the "Fine Dust which falls on Vessels in the Atlantic Ocean," and some other geological as well as zoological researches, were published previously to 1851. Between that year and 1855 he brought out his most considerable contributions to systematic zoology, his monographs on the Cirripedia and the Fossil Lepadidæ.

We come to the first publication of what is now known as Darwinism. It consists of a sketch of the doctrine of Natural Selection, which was drawn up in the year 1839, and copied and communicated to Messrs. Lyell and Hooker in 1844, being a part of the manuscript of a chapter in his "Origin of Species;" also of a private letter addressed to the writer of this memorial in October, 1857, — the publication of which (in the Journal of the Proceedings of the Linnean Society, Zoological Part, iii. 45–53, issued in the summer of 1858) was caused by the reception by Darwin himself of a letter from Mr. Wallace, inclosing a brief and strikingly similar essay on the same subject, entitled "On the Tendency of Varieties to depart indefinitely from the Original Type." Mr. Darwin's action upon the reception of this rival essay was characteristic. His own work was not yet ready, and the fact that it had been for years in preparation was known only to the persons above mentioned. He proposed to have the paper of Mr. Wallace (who was then in the Moluccas) published at once, in anticipation of his own leisurely prepared volume; and it was only under the solicitation of his friends cognizant of the case that his own early sketch and the corroboratory letter were printed along with it.

The precursory essays of Darwin and Wallace, published in the Proceedings of a scientific society, can hardly have been read except by a narrow circle of naturalists. Most thoughtful investigating naturalists were then in a measure prepared for them. But toward the close of the following year (in the autumn of 1859) appeared the volume "On the Origin of Species by means of Natural Selection, or the Preservation of Favored Races in the Struggle for Life," the first and most notable of that series of duodecimos which have been read and discussed in almost every cultured language, and which within the lifetime of their author have changed the face and in some respect the character of natural history, — indeed have almost as deeply affected many other lines of investigation and thought.

In this Academy, where the rise and progress of Darwinian evolution have been attentively marked and its bearings critically discussed, and at this date, when the derivative origin of animal and vegetable species is the accepted belief of all of us who study them, it would be superfluous to give any explanatory account of these now familiar writings; nor, indeed, would the pages which we are accustomed to consecrate to the memory of our recently deceased Associates allow of it. Let us note in passing that the succeeding volumes of the series may be ranked in two classes, one of which is much more widely known than the other. One class is of those which follow up the argument for the origination of species through descent with modification, or which widen its base and illustrate the *modus operandi* of Natural Selection. Such are the two volumes on "Domesticated Animals and Cultivated Plants," illustrating Variation, Inheritance, Reversion, Interbreeding, &c.; the volume on the "Descent of Man, and Selection in Relation to Sex," — which extended the hypothesis to its logical limits, — and that "On the Expression of the Emotions in Man and the Lower Animals," published in 1872, which may be regarded as the last of this series. Since then Mr. Darwin appears to have turned from the highest to the lower forms of life, and to have entered upon the laborious cultivation of new and special fields of investigation, which, although prosecuted on the lines of his doctrine and vivified by its ideas, might seem to be only incidentally connected with the general argument. But it will be found that all these lines are convergent. Nor were these altogether new studies. The germ of the three volumes upon the Relation of Insects to Flowers and its far-reaching consequences, is a little paper, published in the year 1858, "On the Agency of Bees in the Fertilization of Papilionaceous Flowers, and on the Crossing of Kidney Beans"; the first edition of the volume on "The various Contrivances by which Orchids are Fertilized by Insects" appeared in 1862, thus forming the second volume of the whole series; and the two volumes "On the Effects of Cross- and Self-Fertilization in the Vegetable Kingdom," and "The Different Forms of Flowers on Plants of the same Species," which, along with the new edition of "The Fertilization of Orchids," were all published in 1876 and 1877, originated in two or three remarkable papers contributed to the Journal of the Linnean Society in 1862 and 1863, but are supplemented by additional and protracted experiments. The volume on "Insectivorous Plants," and the noteworthy conclusions in respect to the fundamental unity, and therefore common source, of vegetable and animal life, grew out of an observation which the author made in the summer of 1860, when he "was surprised by finding how large a number of insects were caught by the leaves of the common Sun-dew (*Drosera rotundifolia*), on a heath in Sussex." Almost everybody had noticed this; and one German botanist (Roth), just a hundred years ago, had observed and described the movement of the leaf in consequence of the capture. But nothing came of it, or of what had been as long known of our *Dionæa*, beyond a vague wonderment, until Mr. Darwin took up the subject for experimental investigation. The precursor of his volume on "The Movements and Habits of Climbing Plants," published in 1875, as well as of the recent and larger volume on "The Power of Movement in Plants," 1880, was an essay published in the Journal of the Linnean Society in 1865; and this was instigated by an accidental but capital observation made by a correspondent, in whose hands it was sterile; but it became wonderfully fertile when touched by Darwin's genius.* His latest volume, on "The Formation of Vegetable Mould through the Action of Worms," is a development, after long years, of a paper which he read before the Geological Society of London in 1837.

These subsidiary volumes are less widely known than those of the other class; but they are of no less interest, and they are very characteristic of the author's genius and methods, — characteristic also of his laboriousness. For the amount of prolonged observation, watchful care, and tedious experiment they have demanded is as remarkable as the skill in devising simple and effectual modes of investigation is admirable. That he should have had the courage to undertake and the patience to carry on new inquiries of this kind after he had reached his threescore and ten years of age, and after he had attained an unparalleled breadth of influence and wealth of fame, speaks much for

* Mr. Darwin's quickness in divining the meaning of seemingly unimportant things, is illustrated in his study of *Dionæa*. Noting that the trap upon irritation closes at first imperfectly, leaving some room within and a series of small interstices between the crossed spines, but after a time, if there is prey within, shuts down close, he at once inferred that this was a provision for allowing small insects to escape, and for retaining only those large enough to make the long process of digestion remunerative. To test the surmise, he asked a correspondent to visit the habitat of *Dionæa* at the proper season, and to ascertain by the examination of a large number of the traps in action whether any below a certain considerable size were to be found in them. The result confirmed the inference. A comparatively trivial but characteristic illustration of Darwin's confidence in the principle of utility, and a good example of the truth of the dictum, which was by some thought odd when first made, namely, that Darwin had restored teleology to natural history, from which the study of morphology had dissevered it.

his energy and for his devotion to knowledge for its own sake. Indeed, having directed the flow of scientific thought into the new channel he had opened, along which the current set quicker and stronger than he could have expected, he seems to have taken up with fresh delight studies which he had marked out in early years, or topics which from time to time had struck his acute attention. To these he gave himself, quite to the last, with all the spirit and curiosity of youth. Evidently all this amount of work was done for the pure love of it; it was all done methodically, with clear and definite aim, without haste, but without intermission.

It would confidently be supposed that in this case genius and industry were seconded by leisure and bodily vigor. Fortunately Darwin's means enabled him to control the disposition of his time. But the voyage of the Beagle, which was so advantageous to science, ruined his health. A sort of chronic sea-sickness, under which all his work abroad was performed, harassed him ever afterwards. The days in which he could give two hours to investigation or writing were counted as good ones, and for much of his life they were largely outnumbered by those in which nothing could be attempted. Only by great care and the simplest habits was he able to secure even a moderate amount of comfortable existence. But in this respect his later years were the best ones, and therefore the busiest. In them also he had most valuable filial aid. There was nothing to cause much anxiety until his seventy-third birthday had passed, or to excite alarm until the week before his death.

It may without exageration be said that no scientific man, certainly no naturalist, ever made an impression at once so deep, so wide, and so immediate. The name of Linnæus might suggest comparison; but readers and pupils of Linnæus over a century ago were to those of Darwin as tens are to thousands, and the scientific as well as the popular interest of the subjects considered were somewhat in the same ratio. Humboldt, who, like Darwin, began with research in travel, and to whom the longest of lives, vigorous health, and the best opportunities were allotted, essayed similar themes in a more ambitious spirit, enjoyed equal or greater renown, but made no deep impression upon the thought of his own day or of ours. As one criterion of celebrity, it may be noted that no other author we know of ever gave rise in his own active lifetime to a special department of bibliography. Dante-literature and Shakespeare-literature are the growth of centuries; but *Darwinismus* had filled shelves and alcoves and teeming catalogues while the unremitting author was still supplying new and ever novel subjects for comment. The technical term which he chose for a designation of his theory, and several of the phrases originated in explanation of it only twenty-five years ago, have already been engrafted into his mother tongue, and even into other languages, and are turned to use in common as well as in philosophical discourse, without sense of strangeness.

Wonderful indeed is the difference between the reception accorded to Darwin and that met with by his predecessor, Lamarck. But a good deal has happened since Lamarck's day; wide fields of evidence were open to Darwin which were wholly unknown to his forerunner; and the time had come when the subject of the origin and connexion of living forms could be taken up as a research rather than as a speculation. Philosophizers on evolution have not been rare; but Darwin was not one of them. He was a scientific investigator, — a philosopher, if you please, but one of the type of Galileo. Indeed very much what Galileo was to physical science in his time, Darwin is to biological science in ours. This without reference to the fact that the writings of both conflicted with similar prepossessions; and that the Darwinian theory, legitimately considered, bids fair to be placed in this respect upon the same footing with the Copernican system.

An English poet wrote that he awoke one morning and found himself famous. When this happened to Darwin, it was a genuine surprise. Although he had addressed himself simply to scientific men, and had no thought of arguing his case before a popular tribunal, yet "The Origin of Species" was too readable a book upon too sensitive a topic to escape general perusal; and this, indeed, must in some sort have been anticipated. But the avidity with which the volume was taken up, and the eagerness of popular discussion which ensued, were viewed by the author, — as his letters at the time testify, — with a sense of amused wonder at an unexpected and probably transient notoriety.

The theory he had developed was presented by a working naturalist to his fellows, with confident belief that it would sooner or later win acceptance from the younger and more observant of these. The reason why these moderate expectations were much and so soon exceeded are not far to seek, though they were not then obvious to the world in general. Although mere speculations were mostly discountenanced by the investigating naturalists of that day, yet their work and their thoughts were, consciously or unconsciously, tending in the direction of evolution. Even those who manfully rowed against the current were more or less carried along with it, and some of them unwittingly contributed to its force. Most of them in their practical studies had worked up to, or were nearly approaching, the question of the relation of the past inhabitants of the earth to the present, and of the present to one another, in such wise as to suggest inevitably that, somehow or other, descent with modification was eventually to be the explanation. This was the natural outcome of the line of thought of which Lyell early became the cautious and fair-minded expositor, and with which he reconstructed theoretical geology. If Lyell had known as much at first hand of botany or zoölogy as he knew of geology, it is probable that his celebrated chapter on the permanence of species in the "Principles" would have been reconsidered before the work had passed to the ninth edition in 1853. He was convinced that species went out of existence one by one, through natural causes, and that they came in one by one, bearing the impress of their immediate predecessors; but he saw no way to connect the two through natural operations. Nor, in fact, had any of the evolutionists been able to assign real causes capable of leading on such variations as are of well-known occurrence to wider and specific or generic differences. Just here came Darwin. When upon the spot he had perceived that the animals of the Galapagos must be modified forms derived from the adjacent continent, and he soon after worked out the doctrine of natural selection. This supplied what was wanting for the condensation of opinions and beliefs, and the collocation of rapidly accumulating facts, into a consistent and workable scientific theory, under a principle which unquestionably could directly explain much, and might indirectly explain more.

It is not merely that Darwin originated and applied a new principle. Not to speak of Wallace, his contemporary, who came to it later, his countryman, Dr. Wells, as Mr. Darwin points out, "distinctly recognizes the principle of natural selection, and this is the first recognition which has been indicated; but he applied it only to the races of men, and to certain characters alone." Darwin, like the rest of the world, was unaware of this anticipation until he was preparing the fourth edition of his "Origin of Species," in 1866, when he promptly called attention to it, perhaps magnifying its importance. However this be, Darwin appears to have been first and alone in apprehending and working out the results which necessarily come from the interaction of the surrounding agencies and conditions under which plants and animals exist, including, of course, their action upon each other. Personifying the *ensemble* of these and the consequences, — namely, the survival only of the fittest in the struggle for life, — under the term of Natural Selection, Mr. Darwin with the instinct of genius divined, and with the ability of a master worked out its pregnant and far-reaching applications. He not only saw its strong points, but he foresaw its limitations, indicated most of the objections in advance of his opponents, weighed them with judicial mind, and where he could not obviate them, seemed never disposed to underrate their force. Although naturally disposed to make the most of his theory, he distinguished between what he could refer to known causes and what thus far is not referrible to them. Consequently, he kept clear of that common confusion of thought which supposes that natural selection originates the variations which it selects. He believed, and he has shown it to be probable, that external conditions *induce* the actions and changes in the living plant or animal which may lead on to the difference between one species and another; but he did not maintain that they *produced* the changes, or were sufficient scientifically to explain them. Unlike most of his contemporaries in this respect, he appears to have been thoroughly penetrated by the idea that the whole physiological action of the plant or animal is a response of the living organism to the action of the surroundings.

The judicial fairness and openness of Darwin's mind, his penetration and sagacity, his wonderful power of eliciting the meaning of things which had escaped questioning by their very commonness, and of discerning the great significance of causes and interactions which had been disregarded on account of their supposed insignificance, his method of reasoning close to the facts and in contact with the solid ground of nature, his aptness in devising fruitful and conclusive experiments, and in prosecuting nice researches with simple but effectual appliances, and the whole rare combination of qualities which made him *facile princeps* in biological investigation, — all these gifts are so conspicuously manifest in his published writings, and are so fully appreciated, that there is no need to celebrate them in an obituary memorial. The writings also display in no small degree the spirit of the man, and to this not a little of their persuasiveness is due. His desire to ascertain the truth, and to present it purely to his readers, is everywhere apparent. Conspicuous, also, is the absence of all trace of controversy and of everything like pretension; and this is remarkable, considering how censure and how praise were heaped upon him without stint. He does not teach didactically, but takes the reader along with him as his companion in observation and in experiment. And in the same spirit, instead of showing pique to an opponent, he seems always to regard him as a helper in his search for the truth.

Those privileged to know him well will certify that he was one of the most kindly and charming, unaffected, simple-hearted, and lovable of men.

How far and how long the Darwinian theory will hold good, the future will determine. But in its essential elements, apart from *à priori* philosophizing, with which its author had nothing to do, it is an advance from which it is evidently impossible to recede. As has been said of the theory of the Conservation of Energy, so of this: "The proof of this great generalization, like that of all other generalizations, lies mainly in the fact that the evidence in its favor is continually augmenting, while that against it is continually diminishing, as the progress of science reveals to us more and more of the workings of the universe."

[The outlines of a portion of this memorial, written on the day of Mr. Darwin's funeral, were printed in "The Literary World" of May 6.]

JOSEPH DECAISNE.

JOSEPH DECAISNE, the oldest member of the Botanical Section on the foreign list, died at Paris, on the 8th of February last, in the seventy-fifth year of his age. He was elected into this Academy in August, 1846, along with Agassiz and De Verneuil. He was born at Brussels, March 11, 1807, the second of three brothers, one of whom became a distinguished painter, and the other the head of the medical department of the Belgian army. He came to Paris and entered the Jardin des Plantes when a lad of seventeen years, and in its service his whole subsequent life was passed. The young *employé* attracted the attention of Adrien de Jussieu, who, seeing his promise and unusual botanical knowledge, soon placed him at the head of the seed department, and in 1833 made him his *Aide-naturaliste*, thus giving the young gardener opportunity for the studies and researches by which he won a place among the foremost botanists of the time. For more than forty years the administration of the Jardin des Plantes and the duties of the chair of Culture at the Museum were in his hands, he having supplied the place of Mirbel through the closing years of the latter's life, and succeeded him as professor in the year 1851; and these duties he continued to fulfil to the last. He was elected a member of the Institute in 1847, in succession to Dutrochet; for forty years he was one of the editors of, and since the death of his colleague, Adolphe Brongniart, he was the sole editor of the botanical portion of the "Annales des Sciences Naturelles." In the

"Annales" he had published some good botanical papers, the earliest in the year 1831. But his first distinction was gained by his anatomical and physiological researches upon the Madder-plant, a monograph containing the results of which appeared at Brussels in 1837, and was said to be "one of the most able memoirs that has ever been published on the physiological history of plants and their bearing on practical cultivation and manufactures." Two years later, in connection with the chemist, Péligot, he published an investigation of the anatomical structure of the Sugar-beet. His classical memoir upon the structure and development of the Mistletoe appeared in 1840, and is of purely scientific interest. In the year 1841 he showed that the Corallines, which had been wrongly carried over to the animal kingdom with the Corals and their allies, were genuine Seaweeds, disguised by the incorporation of a great amount of lime into their tissues. And about this time, in connection with his friend and former pupil, Thuret, he discovered and illustrated the male organs of the *Fuci*, as well as the mode of impregnation and reproduction, thus initiating the investigations which, in the hands of the late Thuret and others, have revolutionized phycology.

Leaving these researches for his associate to complete and publish, thenceforth Decaisne turned all his attention to phanerogamous botany, morphological and systematic. Two orders were elaborated by him for De Candolle's Prodromus, *Asclepiadaceæ* and *Plantaginaceæ*, the former demanding much minute research; he produced in 1868, in conjunction with Le Maout, that admirable text-book, the "Traité Général de Botanique," profusely illustrated by his own facile pencil, which is well known in the original and in the English translation edited by Sir Joseph Hooker. But the works by which he will be most widely known, and which were connected especially with his directorship of the Jardin des Plantes, are that incomparable series of colored illustrations of fruits, together with descriptive text, known as "Le Jardin Fruitier du Muséum," and his subsidiary investigations and publications upon the *Pomaceæ* and their allies. These important publications began in the year 1858, and were completed only a year or two ago.

Decaisne never married: he lived his simple and devoted life in the house on Rue Cuvier in the Jardin des Plantes, where he died, regretted and beloved, the last of the line of illustrious botanists — such as Mirbel, Adrien de Jussieu, Gaudichaud, and Adolphe Brongniart — who were associated in the administration of this institution thirty or forty years ago.

THEODOR SCHWANN.

Theodor Schwann, the distinguished founder of the animal-cell theory, died on the 11th of January, 1882, in the seventy-second year of his age, having been a Foreign Honorary Member of this Academy for more than thirty years. His death followed closely upon that of Schleiden, the almost equally celebrated founder of the vegetable-cell theory, who died on the 23d of June, 1881. Thus death has associated the two investigators whose labors gave to biology the first impulse in the direction which it has since followed with such triumphant results.

Theodor Schwann was born in Neuss, Düsseldorf, on December 7, 1810. For five years following the completion of his medical studies, he held the position of assistant to Johannes Müller in Berlin. During the next nine years he occupied the chair of anatomy in the Catholic University of Louvain. In 1848 he was called to the University of Liege, where he remained till the time of his death, occupying in succession the chairs of anatomy and physiology. Schwann's classical work, upon which his fame chiefly rests, was published, in 1839, under the title "Microscopical Researches into the Accordance in the Structure and Growth of Animals and Plants." In this work the observations of Schleiden upon vegetables were extended into the animal kingdom, and the cell was recognized as the morphological unit in animals as well as in plants. It is however less from a histological than from a physiological point of view that Schwann's work is to be regarded as marking an era in biological science. The conception of cell life which he formed does not seem to have differed much from that of protoplasmic activity as now understood, but his views in regard to the origin of cells have been entirely supplanted by those of more recent investigators. The doctrine which has for its motto, "Omnis cellula e cellulâ," has taken the place of the theory of "organic crystallization" of the cell from a "cytoblastema."

These researches into cell-structure and growth, though by far the most important work of Schwann, do not constitute his only title to fame. He also pointed out the connection between the growth of organisms and the processes of fermentation and putrefaction, thus marking out a line of research which has since been followed with so much success by Pasteur and others. He was likewise the first to study muscular contraction as a physical process, and to express mathematically the force manifested by the muscular fibres at different periods of their contraction. Among his lesser contributions to physiology are also to be mentioned his observations on the necessity of atmospheric air for the development of the hen's egg; his investigations into the nature of gastric digestion; and his experiments on the importance of bile in the animal economy.

Although Schwann had thus at the age of thirty-five years made discoveries which placed him in the foremost ranks of investigators of nature, his after life was almost a blank as far as the production of scientific work was concerned. Since the year 1845 his name appears but twice in the Royal Society's catalogue, once, in 1858, as the author of a report to the Royal Academy of Sciences of Belgium upon the work of Rameaux on the relation between the size of animals and the capacity and movements of the lungs and heart; and once, in 1870, as the writer of an answer to questions addressed by M. d'Omalius to the physiological members of the Brussels Academy of Sciences in relation to the existence of a special vital force.

No satisfactory reason can be given for Schwann's early withdrawal from the field in which he had won such distinguished honors. The hostility of the Church of which he was a member to biological investigations seems hardly sufficient to account for it, for we find him in 1875 publishing a most indignant denunciation of an attempt made by the Catholic clergy to put him upon record as testifying in favor of the miraculous nature of the phenomena manifested by the notorious Louise Lateau. On this occasion, as Virchow says of him, "His noble and brave heart broke through the snare that had been laid for him, and he had no hesitation in doing honor to truth and in calling lies, lies." His conduct in this affair is, however, scarcely a more striking evidence of his intellectual independence than is afforded by certain passages in his chapter on the Theory of Cells, where he discusses the adaptation to a purpose which is characteristic of organized bodies. On reading these passages one cannot fail to be struck with astonishment that they could have been written by a devout Roman Catholic at a period when evolution, in its application to the organic world, had not yet been formulated as a scientific doctrine.

DEAN STANLEY.

Arthur Penrhyn Stanley, who died in the Deanery of Westminster at London on the 18th of July, 1881, was born at Alderley, Cheshire, on the 13th of December, 1815. His father was the rector of Alderley, but early in his son's life became Bishop of Norwich, where he died in 1849. Arthur Stanley was trained in the best spirit of the Church of England, full of devoutness and reverence, full also of the earnest and broad-minded desire for truth, and of a deep sympathy with the problems and the needs of modern English life. At the age of fourteen he went to Rugby, where Dr. Arnold had been made master only the year before. From his great teacher he received the stimulus and direction of mind and character which, combined with and modified by his natural disposition, very largely controlled his future life. His historical enthusiasm found great encouragement at Rugby, and his conception of the true position of the Church of England owed much both to the teaching and example which were powerful there, and the pupil's life of his teacher — which must always rank very high among English biographies — is at once a monument to Dr. Arnold and a key to much of the writer's character and life.

In 1834 Stanley went to Oxford, where his career was very brilliant. He gained the Ireland Scholarship, won the Newdigate prize for his English poem, "The Gipsies," took a first class in classics, and gained the Latin Essay prize in 1839 and the English Essay and Theological prizes in 1840, when he was elected a Fellow of University College. For twelve years he was tutor of his College. He was select preacher in 1845–46, was secretary of the Oxford University Commission from 1850 to 1852, and Regius Professor of Ecclesiastical History and Canon of Christchurch. Indeed from the time when he first became a student his association with the University filled a large part of his life.

In 1850 he became Canon of Canterbury, and in 1852 made his first journey to the East, which resulted in his book on Sinai and Palestine, which has given remarkable vividness and clearness to the geography and associations of the Holy Land. He visited the East again in 1862 in the company of the Prince of Wales, and on this journey he employed the unusual advantages of his position for the investigation and illumination of some points of geography and antiquity which had long been obscure.

In 1863 he was made Dean of Westminster, and held until his death that interesting and influential place with which his name will always be associated. He became a Foreign Honorary Member of this Academy in 1876.

These are the chief landmarks of Dean Stanley's quiet life. The works which he produced appear to have, as we look back upon them, a singular unity of character and purpose. The basis of them all is history, but nowhere is the manifoldness of history so manifest, its value as the ground in which all present life has its roots, and from which it must draw its inspirations and illustrations. The most characteristic works are his "Lectures on the History of the Jewish Church," published from 1863 to 1865, his "Lectures on the History of the Eastern Church," published in 1861, his "Commentary on the Epistles to the Corinthians," published in 1854, his "Essays on Church and State," published in 1870, his "Memorials of Westminster Abbey," published in 1867, and his last book on "Christian Institutions," published shortly before his death. In all these works there is a wonderful vitality. No historical student of our time has surpassed Dean Stanley in the power of realizing a period of history, of catching its spirit, of sympathizing with the feelings and motives of its men, and of making it live in light and color on the printed stage.

But he is far more than a mere historical artist. He is always full of an interest, which is almost painfully eager and intense, in the present problems and conditions of the world. The past is rich to him in suggestions, illustrations, warnings, precedents, which throw remarkable illumination on his own times. The identity of human nature in all times is the conviction which underlies all his writing. It is, indeed, one of the first articles of his religion. It proceeds at once from that profound belief in God and His Fatherhood which is the substance of this teacher's creed. Hence, even so remote a book as the "Memorials of Westminster Abbey" is full of application to the writer's times. The dead truly speak out of their tombs. There is hardly a political puzzle now bewildering the English brain, hardly an exhortation now heeded by the English heart, which is not to be found breaking forth somewhere, most unexpectedly but most naturally, in his descriptions of the venerable London church. And his "Commentary on the Epistles to the Corinthians" has passages which read like a latter-day pamphlet from a prophet of the nineteenth century.

Among our historians Dean Stanley must always be remembered for this desire and this purpose to translate the past to the present. He does not make the dead past live for nothing. There is a purpose in everything which he has written. And yet he is too true an artist and has too genuine a love for the beauty of an historic picture or a graphic word to let his pages become dull and didactic. His literary skill is full of charm. Sometimes involved and complicated, and almost obscure, as if he wrote in haste and stress of thought, but generally of a crystal clearness, his style flows on, always full of life and movement. It is perhaps too fervid for the pure historian perfectly to approve, but it bears the best test of never growing dull.

On the ecclesiastical life of the time the work of Dean Stanley has had great influence. There was not a more loyal son of the Church of England than he, but no man in England saw her dangers more. More than once it seemed as if his was the power which saved her from some step which would have lost for her the reverence of thoughtful men. His last work, the "Christian Institutions," is an assertion of the place of common-sense and historical induction in religious thought which is most valuable. In 1866, when Convocation undertook to pass gratuitous condemnation on Bishop Colenso, Stanley's manly protest was the strongest voice of rebuke to the persecuting spirit. His whole life was a perpetual enlargement and enlightenment to his Church, and he has probably helped as much as any Churchman of his generation to clear the ground for the great progress which the Church of England is to make and the great work which she is to do in the next hundred years.

It is easy to see the limitations of such a life and such a work as his. He was supremely human. It was men, and not things, that interested him in the world. Hence he paid little heed to the wonderful discoveries of natural science which have illustrated our age, and probably had little knowledge of them. And yet he reached a true relation with them through his interest in the men who made them and through his eagerness to complete his historic picture with the image of the scientific man. His funeral sermons on the deaths of Sir John Herschel and of Sir Charles Lyell are full of delight in the higher aspects of natural science. He was a beautiful instance of the way in which the historical genius makes all knowledges and arts its tributaries.

It was more than a happy chance that so devout and humane a nature should have found its home in Westminster Abbey. While he was Dean he himself felt so deeply that he made all men who came there feel what a great representative value belonged to the historic church where God had been worshipped for eight hundred years and where so many of the greatest Englishmen were buried. His broad treatment of the Abbey did much to keep the religion of England broad and free.

The personal charm of Dean Stanley was felt by all who came into his presence. It consisted of perfect simplicity and self-forgetfulness, ready sympathy with all who cared for truth, eager curiosity, and an imagination which never failed and which drew out the poetry of every situation. His home in early days at Oxford, and of late in Westminster, was the resort of the most earnest and cultivated men of England, and foreigners from every land who came with sympathy and love for truth found the most hospitable welcome. For the last five years of the Dean's life a shadow rested on its brightest side, but the cordial hospitality and hearty greeting never failed.

In the autumn of 1878 Dean Stanley made a memorable visit to America, which served to show how truly he was honored here. Few Englishmen have come to this country who have found so many friends among the best and most thoughtful men as he. And the true, unaffected interest which he had always felt in our country — an interest neither patronizing nor contemptuous, but frank and hearty and sincere — was deepened by his short and hurried journey. The volume of his addresses in America is the best record of how thoughtfully he observed our country and how well he understood it.

His death was as serene and peaceful as his life. After a few short days of sickness he passed away in the midst of the friends and the associations that he loved. His memory remains as one of the most brilliant and attractive in this rich generation of Englishmen, and the Academy may well rejoice that his name will always stand on the list of its honored members.

Since the last Report, the Academy has received an accession of twenty new Members, viz.: eleven Resident Fellows; eight Associate Fellows; and one Foreign Honorary Member. One Member has resigned his fellowship. The list of the Academy corrected to the date of this Report is hereto added. It includes one hundred and eighty-eight Resident Fellows, ninety-three Associate Fellows, and sixty-nine Foreign Honorary Members.

LIST

OF THE FELLOWS AND FOREIGN HONORARY MEMBERS.

FELLOWS. — 188.

(Number limited to two hundred.)

CLASS I. — *Mathematical and Physical Sciences.* — 66.

SECTION I. — 6.

Mathematics.

William E. Byerly, Cambridge.
Benjamin A. Gould, Cambridge.
Gustavus Hay, Boston.
James M. Peirce, Cambridge.
John D. Runkle, Brookline.
Edwin P. Seaver, Newton.

SECTION II. — 12.

Practical Astronomy and Geodesy.

J. Ingersoll Bowditch, Boston.
Alvan Clark, Cambridgeport.
Alvan G. Clark, Cambridgeport.
George B. Clark, Cambridgeport.
John R. Edmands, Cambridge.
Henry Mitchell, Roxbury.
Robert Treat Paine, Brookline.
Edward C. Pickering, Cambridge.
William A. Rogers, Cambridge.
Arthur Searle, Cambridge.
Leopold Trouvelot, Cambridge.
Henry L. Whiting, Tisbury.

SECTION III. — 33.

Physics and Chemistry.

A. Graham Bell, Cambridge.
Clarence J. Blake, Boston.
Francis Blake, Auburndale.
John H. Blake, Boston.
Thos. Edwards Clark, Williamstown.
W. S. Clark, Amherst.
Josiah P. Cooke, Cambridge.
James M. Crafts, Boston.
Charles R. Cross, Boston.
William P. Dexter, Roxbury.
Amos E. Dolbear, Medford.
Charles W. Eliot, Cambridge.
Moses G. Farmer, Newport.
Thomas Gaffield, Boston.
Wolcott Gibbs, Boston.
Frank A. Gooch, Cambridge.
Augustus A. Hayes, Brookline.
Henry B. Hill, Cambridge.
N. D. C. Hodges, Salem.
Eben N. Horsford, Cambridge.
T. Sterry Hunt, Montreal.
Charles L. Jackson, Cambridge.
Joseph Lovering, Cambridge.
William R. Nichols, Boston.
John M. Ordway, Boston.
Robert H. Richards, Boston.
Edward S. Ritchie, Boston.
Stephen P. Sharples, Cambridge.
Francis H. Storer, Jamaica Plain.
John Trowbridge, Cambridge.
Cyrus M. Warren, Brookline.
Charles H. Wing, Boston.
Edward S. Wood, Cambridge.

SECTION IV. — 15.

Technology and Engineering.

George R. Baldwin, Woburn.
John M. Batchelder, Cambridge.
Charles O. Boutelle, Washington.
Henry L. Eustis, Cambridge.
James B. Francis, Lowell.
John B. Henck, Boston.
E. D. Leavitt, Jr., Cambridgeport.
William R. Lee, Roxbury.
Frederic W. Lincoln, Boston.
Hiram F. Mills, Lawrence.
Alfred P. Rockwell, Boston.
Charles S. Storrow, Boston.
William R. Ware, New York.
William Watson, Boston.
Morrill Wyman, Cambridge.

Class II. — *Natural and Physiological Sciences.* — 58.

Section I. — 8.

Geology, Mineralogy, and Physics of the Globe.

Thomas T. Bouvé,	Boston.
William T. Brigham,	Boston.
Algernon Coolidge,	Boston.
William O. Crosby,	Boston.
John L. Hayes,	Cambridge.
William H. Niles,	Cambridge.
Nathaniel S. Shaler,	Cambridge.
Charles U. Shepard,	Amherst.

Section II. — 8.

Botany.

William G. Farlow,	Cambridge.
George L. Goodale,	Cambridge.
Asa Gray,	Cambridge.
H. H. Hunnewell,	Wellesley.
Charles S. Sargent,	Brookline.
Charles J. Sprague,	Boston.
Edward Tuckerman,	Amherst.
Sereno Watson,	Cambridge.

Section III. — 20.

Zoölogy and Physiology.

Alex. E. R. Agassiz,	Cambridge.
Joel A. Allen,	Cambridge.
Robert Amory,	Brookline.
Nath. E. Atwood,	Provincetown.
James M. Barnard,	Boston.
Henry P. Bowditch,	Boston.
Edward Burgess,	Boston.
Samuel Cabot,	Boston.
John Dean,	Waltham.
Hermann A. Hagen,	Cambridge.
Charles E. Hamlin,	Cambridge.
Alpheus Hyatt,	Boston.
Samuel Kneeland,	Boston.
Theodore Lyman,	Boston.
Edward S. Morse,	Salem.
James J. Putnam,	Boston.
Samuel H. Scudder,	Cambridge.
D. Humphreys Storer,	Boston.
Henry Wheatland,	Salem.
James C. White,	Boston.

Section IV. — 22.

Medicine and Surgery.

Samuel L. Abbot,	Boston.
Henry J. Bigelow,	Boston.
Henry I. Bowditch,	Boston.
Benjamin E. Cotting,	Roxbury.
Frank W. Draper,	Boston.
Thomas Dwight,	Boston.
Robert T. Edes,	Roxbury.
Calvin Ellis,	Boston.
Charles F. Folsom,	Boston.
Richard M. Hodges,	Boston.
Oliver W. Holmes,	Boston.
Robert W. Hooper,	Boston.
Alfred Hosmer,	Watertown.
Edward Jarvis,	Dorchester.
Francis Minot,	Boston.
John P. Reynolds,	Boston.
Wm. L. Richardson,	Boston.
George C. Shattuck,	Boston.
J. Baxter Upham,	Boston.
Charles E. Ware,	Boston.
John C. Warren,	Boston.
Henry W. Williams,	Boston.

Class III. — *Moral and Political Sciences.* — 64.

Section I. — 14.

Philosophy and Jurisprudence.

James B. Ames,	Cambridge.
Charles S. Bradley,	Providence.
Phillips Brooks,	Boston.
James F. Clarke,	Jamaica Pl.
Charles C. Everett,	Cambridge.
Horace Gray,	Boston.
John C. Gray,	Boston.
Laurens P. Hicock,	Northampton.
Oliver W. Holmes, Jr.,	Boston.
Mark Hopkins,	Williamstown.
C. C. Langdell,	Cambridge.
John Lowell,	Boston.
Henry W. Paine,	Cambridge.
James B. Thayer,	Cambridge.

Section II. — 20.

Philology and Archæology.

Ezra Abbot,	Cambridge.
William S. Appleton,	Boston.
William P. Atkinson,	Boston.
Lucien Carr,	Cambridge.
Henry G. Denny,	Boston.
Epes S. Dixwell,	Cambridge.
William Everett,	Quincy.
William W. Goodwin,	Cambridge.
Ephraim W. Gurney,	Cambridge.
Henry W. Haynes,	Boston.
Charles R. Lanman,	Cambridge.
John D. Long,	Boston.
Bennett H. Nash,	Boston.
Frederic W. Putnam,	Cambridge.
Chandler Robbins,	Boston.
John L. Sibley,	Cambridge.
E. A. Sophocles,	Cambridge.
John W. White,	Cambridge.
Justin Winsor,	Cambridge.
Edward J. Young,	Watertown.

Section III. — 19.

Political Economy and History.

Chas. F. Adams, Jr.,	Quincy.
Henry Adams,	Boston.
Edward Atkinson,	Boston.
John Cummings,	Woburn.
Charles Deane,	Cambridge.
Charles F. Dunbar,	Cambridge.
Samuel Eliot,	Boston.
George E. Ellis,	Boston.
Edwin L. Godkin,	New York.
William Gray,	Boston.
Edward Everett Hale,	Boston.
Henry P. Kidder,	Boston.
Henry C. Lodge,	Boston.
Francis Parkman,	Brookline.
Andrew P. Peabody,	Cambridge.
Joseph S. Ropes,	Boston.
Nathaniel Thayer,	Boston.
Henry W. Torrey,	Cambridge.
Robert C. Winthrop,	Boston.

Section IV. — 11.

Literature and the Fine Arts.

Charles F. Adams,	Boston.
George S. Boutwell,	Groton.
J. Elliot Cabot,	Brookline.
Francis J. Child,	Cambridge.
Charles G. Loring,	Boston.
James Russell Lowell,	Cambridge.
Charles Eliot Norton,	Cambridge.
Thomas W. Parsons,	Wayland.
Charles C. Perkins,	Boston.
H. H. Richardson,	Brookline.
John G. Whittier,	Amesbury.

ASSOCIATE FELLOWS. — 93.

(Number limited to one hundred.)

Class I. — *Mathematical and Physical Sciences.* — 37.

Section I. — 8.

Mathematics.

Charles Avery,	Clinton, N.Y.
E. B. Elliott,	Washington, D.C.
William Ferrel,	Washington, D.C.
Thomas Hill,	Portland, Me.
Simon Newcomb,	Washington, D.C.
H. A. Newton,	New Haven, Conn.
James E. Oliver,	Ithaca, N.Y.
T. H. Safford,	Williamstown, Mass.

Section II. — 13.

Practical Astronomy and Geodesy.

S. Alexander,	Princeton, N.J.
W. H. C. Bartlett,	Yonkers, N.Y.
J. H. C. Coffin,	Washington, D.C.
Henry Draper,	New York.
Wm. H. Emory,	Washington, D.C.
Asaph Hall,	Washington, D.C.
J. E. Hilgard,	Washington, D.C.
George W. Hill,	Nyack, N.Y.
Elias Loomis,	New Haven, Conn.
Maria Mitchell,	Poughkeepsie, N.Y.
C. H. F. Peters,	Clinton, N.Y.
George M. Searle,	New York.
Chas. A. Young,	Princeton, N.J.

Section III. — 11.

Physics and Chemistry.

F. A. P. Barnard,	New York.
J. Willard Gibbs,	New Haven, Conn.
S. W. Johnson,	New Haven, Conn.
John Le Conte,	Berkeley, Cal.
A. M. Mayer,	Hoboken, N.J.
W. A. Norton,	New Haven, Conn.
Ogden N. Rood,	New York.
H. A. Rowland,	Baltimore.
L. M. Rutherfurd,	New York.
Benj. Silliman,	New Haven, Conn.
J. L. Smith,	Louisville, Ky.

Section IV. — 5.

Technology and Engineering.

Henry L. Abbot,	New York.
A. A. Humphreys,	Washington, D.C.
William Sellers,	Philadelphia.
George Talcott,	Albany, N.Y.
W. P. Trowbridge,	New Haven, Conn.

Class II. — *Natural and Physiological Sciences.* — 28.

Section I. — 13.

Geology, Mineralogy, and Physics of the Globe.

George J. Brush,	New Haven, Conn.
James D. Dana,	New Haven, Conn.
J. W. Dawson,	Montreal, Canada.
J. C. Fremont,	New York.
F. A. Genth,	Philadelphia.
Arnold Guyot,	Princeton, N.J.
James Hall,	Albany, N.Y.
F. S. Holmes,	Charleston, S.C.
Clarence King,	Washington, D.C.
Joseph Le Conte,	Berkeley, Cal.
J. Peter Lesley,	Philadelphia.
R. Pumpelly,	Newport, R.I.
Geo. C. Swallow,	Columbia, Mo.

SECTION II. — 3.

Botany.

A. W. Chapman, Apalachicola, Fla.
G. Engelmann, St. Louis, Mo.
Leo Lesquereux, Columbus, Ohio.

SECTION III. — 7.

Zoölogy and Physiology.

S. F. Baird, Washington, D.C.
J. C. Dalton, New York.
J. L. Le Conte, Philadelphia.
Joseph Leidy, Philadelphia.
O. C. Marsh, New Haven, Conn.
S. Weir Mitchell, Philadelphia.
A. S. Packard, Jr., Providence.

SECTION IV. — 5.

Medicine and Surgery.

Fordyce Barker, New York.
John S. Billings, Washington, D.C.
Jacob M. Da Costa, Philadelphia.
W. A. Hammond, New York.
Alfred Stillé, Philadelphia.

CLASS III. — *Moral and Political Sciences.* — 28.

SECTION I. — 8.

Philosophy and Jurisprudence.

D. R. Goodwin, Philadelphia.
R. G. Hazard, Peacedale, R.I.
Nathaniel Holmes, St. Louis, Mo.
James McCosh, Princeton, N. J.
Charles S. Peirce, New York.
Noah Porter, New Haven, Conn.
Isaac Ray, Philadelphia.
Jeremiah Smith, Dover, N.H.

SECTION II. — 9.

Philology and Archæology.

A. N. Arnold, Pawtuxet, R. I.
D. C. Gilman, Baltimore.
A. C. Kendrick, Rochester, N.Y.
George P. Marsh, Rome.
A. S. Packard, Brunswick, Me.
E. E. Salisbury, New Haven, Conn.
A. D. White, Ithaca, N.Y.
W. D. Whitney, New Haven, Conn.
T. D. Woolsey, New Haven, Conn.

SECTION III. — 6.

Political Economy and History.

George Bancroft, Washington, D.C.
S. G. Brown, Clinton, N.Y.
Henry C. Lea, Philadelphia.
J. H. Trumbull, Hartford, Conn.
M. F. Force, Cincinnati.
W. G. Sumner, New Haven, Conn.

SECTION IV. — 5.

Literature and the Fine Arts.

James B. Angell, Ann Arbor, Mich.
L. P. di Cesnola, New York.
F. E. Church, New York.
R. S. Greenough, Florence.
William W. Story, Rome.

FOREIGN HONORARY MEMBERS. — 69.

(Appointed as vacancies occur.)

Class I. — *Mathematical and Physical Sciences.* — 24.

Section I. — 6.

Mathematics.

John C. Adams,	Cambridge.
Sir George B. Airy,	Greenwich.
Brioschi,	Milan.
Arthur Cayley,	Cambridge.
Liouville,	Paris.
J. J. Sylvester,	Baltimore.

Section II. — 5.

Practical Astronomy and Geodesy.

Arthur Auwers,	Berlin.
Döllen,	Pulkowa.
H. A. E. A. Faye,	Paris.
Emile Plantamour,	Geneva.
Otto Struve,	Pulkowa.

Section III. — 10.

Physics and Chemistry.

Berthelot,	Paris.
R. Bunsen,	Heidelberg.
M. E. Chevreul,	Paris.
J. Dumas,	Paris.
H. Helmholtz,	Berlin.
A. W. Hofmann,	Berlin.
G. Kirchhoff,	Berlin.
Balfour Stewart,	Manchester.
G. G. Stokes,	Cambridge.
F. Wöhler,	Göttingen.

Section IV. — 3.

Technology and Engineering.

R. Clausius,	Bonn.
F. M. de Lesseps,	Paris.
Sir Wm. Thomson,	Glasgow.

Class II. — *Natural and Physiological Sciences.* — 24.

Section I. — 6.

Geology, Mineralogy, and Physics of the Globe.

Barrande,	Prague.
Des Cloizeaux,	Paris.
James Prescott Joule,	Manchester.
C. F. Rammelsberg,	Berlin.
A. C. Ramsay,	London.
Sir Edward Sabine,	London.

Section II. — 6.

Botany.

J. G. Agardh,	Lund.
George Bentham,	London.
Alphonse de Candolle,	Geneva.
Oswald Heer,	Zurich.
Sir Joseph D. Hooker,	London.
Nägeli,	Munich.

SECTION III. — 8.

Zoölogy and Physiology.

T. L. W. Bischoff,	Munich.
Milne Edwards,	Paris.
Albrecht Kölliker,	Würzburg.
Rudolph Leuckart,	Leipsic.
Richard Owen,	London.
C. Th. von Siebold,	Munich.
J. J. S. Steenstrup,	Copenhagen.
Valentin,	Berne.

SECTION IV. — 4.

Medicine and Surgery.

C. E. Brown-Séquard,	Paris.
F. C. Donders,	Utrecht.
Sir James Paget,	London.
Virchow,	Berlin.

CLASS III. — *Moral and Political Sciences.* — 21.

SECTION I. — 3.

Philosophy and Jurisprudence.

Sir Henry Sumner Maine,	London.
James Martineau,	London.
Sir James F. Stephen,	London.

SECTION II. — 7.

Philology and Archæology.

Georg Curtius,	Leipsic.
Pascual de Gayangos,	Madrid.
Benjamin Jowett,	Oxford.
Lepsius,	Berlin.
Max Müller,	Oxford.
H. A. J. Munro,	Cambridge.
Sir H. C. Rawlinson,	London.

SECTION III. — 8.

Political Economy and History.

Ernst Curtius,	Berlin.
W. Ewart Gladstone,	London.
Charles Merivale,	Ely.
F. A. A. Mignet,	Paris.
Mommsen,	Berlin.
Mark Pattison,	Oxford.
Von Ranke,	Berlin.
William Stubbs,	Oxford.

SECTION IV. — 3.

Literature and the Fine Arts.

Gérôme,	Paris.
John Ruskin,	Coniston.
Alfred Tennyson,	Isle of Wight.

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